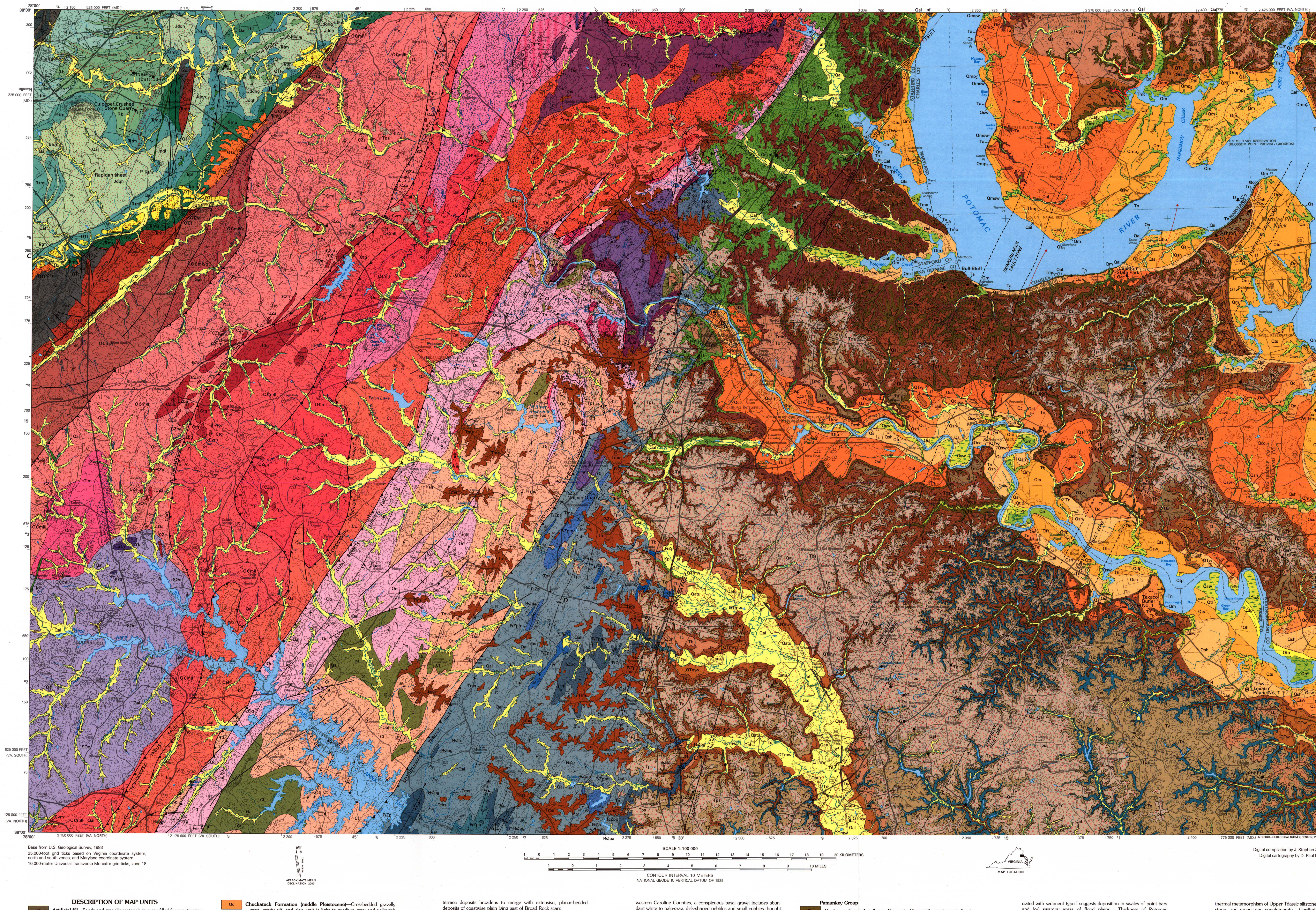
U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

GEOLOGIC INVESTIGATIONS SERIES
MAP I–2607 (SHEET 1 OF 2)
Explanatory pamphlet accompanies map



Base from U.S. Geological Survey, 1983
25,000-foot grid ticks based on Virginia coordinate system, north and south zones, and Maryland coordinate system
10,000-meter Universal Transverse Mercator grid ticks, zone 18

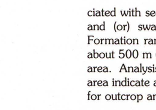
APPROXIMATE MEAN DECLINATION, 2000

SCALE 1:100 000

20 KILOMETERS

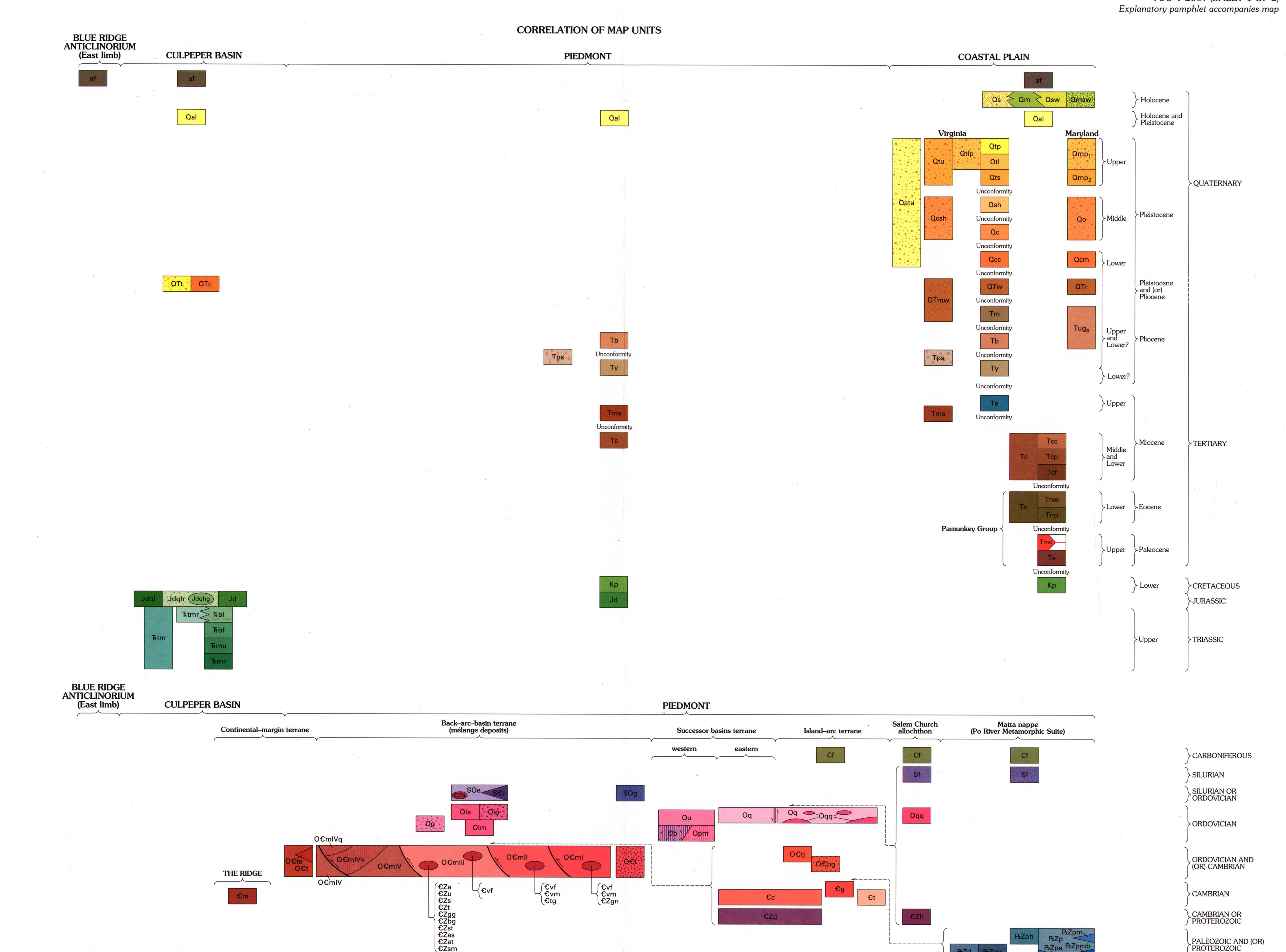
10 MILES

CONTOUR INTERVAL 10 METERS
NATIONAL GEODETIC VERTICAL DATUM OF 1929



Digital compilation by J. Stephen Schindler
Digital cartography by D. Paul Mathieux

CORRELATION OF MAP UNITS



DESCRIPTION OF MAP UNITS

af — **Artificial fill**—Sandy and gravelly materials in areas filled for construction of roads, highways, bridges, and dams

UPPER MESOZOIC AND CENOZOIC DEPOSITS OF THE ATLANTIC COASTAL PLAIN

Deposits of Present-day Streams and Valleys

Qs — **Sand (Holocene)**—Pale-gray to light-yellowish-gray, fine to coarse, poorly sorted to well-sorted; locally, unit contains sparse shell fragments and whole valves of mollusks reworked from older strata. Constitutes deposits of low natural levees separating main channel of tidal Rappahannock River from bordering swamps and marshes. Also includes sediments of narrow beaches and small sand bars and spits developed at mouths of streams flowing into tidal rivers. Thickness commonly 2 to 8 m (7–26 ft)

Qm — **Marsh deposits (Holocene)**—Soft mud and muddy sand, medium- to dark-gray; may include grayish-brown peat or peaty sand and mud. Deposits are covered intermittently by water, may be vegetated by rushes and other grasslike plants. Locally, unit includes shells of fresh- to brackish-water mollusks. Thickness generally less than 6 m (20 ft)

Qsw — **Swamp deposits (Holocene)**—Mud, muddy sand, and muck; brownish gray and brownish to grayish black. Contains abundant decaying leaf and stem material and trunks of trees. Unit thickly vegetated by shrubs and trees; occurs as a thin veneer (less than 3 m (10 ft) thick) directly overlying alluvial fill of stream valleys; commonly grades downvalley into marsh deposits

Qmsw — **Marsh and swamp deposits, undivided (Holocene)**

Qal — **Alluvium (Holocene and Pleistocene)**—Fine to coarse gravelly sand and sandy gravel, silt, and clay; unit is light to medium gray and yellowish gray; clasts consist mainly of vein quartz, quartzite, and other metamorphic rocks. Deposited mainly in channel, point-bar, and flood plain environments; grades into colluvium along steeper valley walls at margins of unit. Unit is mostly Holocene but, locally, may include low-lying Pleistocene terrace deposits. Thickness along major streams is as much as 15 m (49 ft)

Surficial Deposits of Riverine and Estuarine Terraces in Virginia

Tabb Formation (upper Pleistocene)—Sand, gravel, silt, and clay underlying low terraces along the tidal Potomac and Rappahannock Rivers. In eastern part of map area in Virginia, unit is commonly subdivided into the Sedgefield, Lynnhaven, and Poquoson Members which are believed to represent three episodes of cut and fill during Sangamonian and post-Sangamonian(?) time. On the basis of lithology and stratigraphic position, the Tabb Formation is equivalent to the Kent Island and Maryland Point Formations as mapped in Maryland along the northern side of the Potomac River (McCartan, 1989a)

Qtp — Poquoson Member—Medium to coarse pebbly sand grading upward into clayey fine sand and silt, light- to dark-gray; underlies remnants of lowest river terrace (altitude ranging from sea level to 3.5 m (11.5 ft)) in Loretto and Rollins Fork quadrangles. Commonly 5 to 8 m (16–26 ft) thick

Qtl — Lynnhaven Member—Fine to coarse gray sand, pebbly and cobbly, grading upward into clayey and silty fine sand and sandy silt; locally, at base of unit, medium to coarse crossbedded sand and clayey silt containing abundant plant material fill channels cut into underlying stratigraphic units. Underlies river terraces ranging in altitude from 3 to 6.5 m (10–21.3 ft). Unit is as much as 12 m (39 ft) thick

Qts — Sedgefield Member—Pebbly to bouldery, fine to coarse, crossbedded sand grading upward to sandy and clayey silt; unit is pale gray to medium gray and yellowish gray. Diatom assemblage in upper part of unit at Mathias Point Neck indicates a brackish-water depositional environment. Unit constitutes surficial deposit of extensive terraces (altitude 7.5 to 10 m (24.6–33 ft)) along Potomac and Rappahannock Rivers. Thickness is as much as 15 m (49 ft)

Qtlp — Lynnhaven and Poquoson Members, undivided

Qtu — **Tabb Formation, undivided**

Qsh — **Shirley Formation (middle Pleistocene)**—Fine to coarse sand, in part pebbly and bouldery, light- to medium-gray and pale-yellowish-gray; grades upward to silty fine sand and sandy silt, pale-gray to pinkish-gray. Constitutes surficial deposits of terraces (altitude 10.5 to 14 m (34.4–46 ft)) in Potomac River and Rappahannock River valleys. Unit typically exposed in southern Passapatanzy quadrangle where extensive borrow pits in terraces along the Rappahannock River show coarse sand and pebble-to-boulder gravel filling fluvial channels. Clay-silt plugs rich in organic matter represent fill of abandoned channels. On the basis of lithology, stratigraphic position, and altitude of depositional surfaces, the Omar Formation (Qo) as mapped in Charles County, Maryland (see this map and McCartan, 1989a) is equivalent to the Shirley Formation and, in part, the Chuckatuck Formation. The coral *Astrangia* from the Shirley Formation in the lower Rappahannock River area has yielded a uranium-thorium age of 184±20 ka (Mixon and others, 1982). Unit is commonly 10 to 20 m (33–66 ft) thick

Qc — **Chuckatuck Formation (middle Pleistocene)**—Crossbedded gravelly sand, sandy silt, and clay; unit is light to medium gray and yellowish gray; commonly weathers yellowish orange and reddish brown. Constitutes surficial deposits of mid-level estuarine terraces (altitude 15 to 18 m (50–60 ft)). Base of unit is inset well below base of Charles City Formation. Unit separated from younger, topographically lower Shirley Formation by low estuarine scarps. Commonly 5 to 15 m (16–49 ft) thick

Qcsh — **Chuckatuck and Shirley Formations, undivided**

Qcc — **Charles City Formation (lower Pleistocene)**—Upward-fining sequence consists of a basal gravelly sand grading upward to moderately well sorted, medium to fine sand, silt, and clay; unit is light to medium gray; oxidizes to dark yellowish orange and yellowish brown. Constitutes surficial deposits of terraces at altitudes of 23 to 26 m (75–85 ft) in eastern part of the Virginia map area; ranges in altitude from 26 to 28 m (85–92 ft) along upper Rappahannock estuary at Fredericksburg. Unit is extensively preserved in high-level relict meander of Potomac River in parts of Dahlgren and Rollins Fork 7.5-min quadrangles; there, sand and silt in upper part of section contain abundant small invertebrate burrows which suggest an estuarine depositional environment. On the basis of stratigraphic position, lithology, and altitude of depositional surfaces, the Chicamuxen Church Formation (Qcm) as mapped northeast of the Potomac River in Charles County, Maryland (see this map and McCartan, 1989a), is equivalent, at least in part, to the Charles City Formation. Thickness is as much as 18 m (59 ft)

Qatu — **Alluvial terrace deposits, undivided (Pleistocene)**—Fine to coarse gravelly sand, sandy gravel, silt, and clay, very poorly exposed. Constitutes surficial deposits of low-level terraces along the Poni and Mattaponi Rivers and tributaries in Caroline County, Virginia, and Nanjemoy and Burgess Creeks in Calvert County, Maryland

QTw — **Windsor Formation (lower Pleistocene or upper Pliocene)**—Fine to coarse sand, gravel, silt, and clay; unit is gray, yellowish brown, and reddish brown. Gravel is mostly vein quartz and quartzite but includes pebbles and cobbles of red mudstone, amygdaloidal basalt, and diabase derived from the early Mesozoic Culpeper basin and minor gneiss and schist from the Piedmont. Unit is surficial deposit of terraces ranging in altitude from 30.5 m (100 ft) in easternmost part of the Virginia map area to about 35 m (115 ft) in upper Rappahannock River estuary area. Unit crops out extensively in Loretto 7.5-min quadrangle and in west-central part of Rollins Fork 7.5-min quadrangle where it is inset well below base of older Moorings unit and is separated from the Moorings by a distinct scarp. The Windsor Formation and the Ravens Crest Formation as mapped in Charles and St. Marys Counties, Maryland, are equivalent units (McCartan and others, 1996). The name Ravens Crest Formation replaces the Park Hall Formation as defined by McCartan (1989a, b). Thickness is as much as 12 m (39 ft)

Tm — **Moorings unit of Oaks and Coch (1973) (upper Pliocene)**—Quartzose sand and sandy gravel, white, light-gray, and grayish-yellow; clasts consist of well-rounded pebbles, cobbles, and boulders of quartz and quartzite; chert is a minor constituent. Unit occurs as surficial deposits of high-level terraces along Rappahannock River; altitude of depositional surfaces ranges from about 38 m (125 ft) in Rollins Fork quadrangle to as much as 44 m (144 ft) in Fredericksburg area. The deposits are thought to be fluvial and estuarine equivalents of marginal-marine facies of the Moorings unit in the outer Coastal Plain along and just west of the Surry scarp (Mixon and others, 1989a). Thickness is 3 to 9 m (10–30 ft)

QTmw — **Windsor Formation and (or) Moorings unit of Oaks and Coch (1973) (lower Pleistocene or upper Pliocene)**—Poorly exposed sand and gravel of high-level terraces (altitude 44 to 49 m (144–161 ft)) paralleling upper parts of Mattaponi River and tributaries in northern Caroline County and eastern Spotsylvania County, Virginia. Sediments are thought to be fluvial equivalents of estuarine terrace deposits along lower reaches of the Mattaponi River

Tb — **Bacons Castle Formation (upper Pliocene)**—Upward-fining fluvial sequence includes two main sediment types: (1) Lower 3 to 6 m (10–20 ft) of unit consists of medium to coarse gravelly sand and sandy gravel, poorly sorted, thick- to very thick bedded, trough-crossbedded; unit is light to medium gray; oxidizes to yellowish orange. Pebble- to cobble-sized clasts are mostly vein quartz, quartzite, and sandstone; chert is common in Potomac River drainage, rare elsewhere; deeply weathered basalt and other crystalline rocks occur in Rappahannock River drainage. Rounded clasts of ironstone (iron-oxide cemented sand), derived from erosion of ironstone beds in the directly underlying Yorktown Formation, indicate an interval of diagenesis and weathering of the Yorktown prior to deposition of Bacons Castle beds. The coarse basal sands and gravels grade upward to (2) poorly sorted, sandy and clayey silt and silty clay, gray to pink, interbedded with thin- to very thick bedded fine sand; sandy silt and clay of upper part of unit are generally very thick bedded or massive, grade upward to dark-red and reddish-brown soil. The relatively fine sediments of the upper part of the Bacons Castle are interpreted as overbank deposits. Formation is as much as 18 m (59 ft) thick. Constitutes high-level terrace deposits of Rappahannock and Potomac Rivers inset below level of adjacent, more dissected upland areas underlain by the Yorktown Formation and Unit Tps. Relict terrace surfaces range in altitude from about 47 to 53 m (154–174 ft). In southeastern corner of map area, outcrop of riverine terrace deposits broadens to merge with extensive, planar-bedded deposits of coastwise plain lying east of Broad Rock scarp

Surficial Deposits of Riverine and Estuarine Terraces in Maryland

Maryland Point Formation (upper Pleistocene)—Sand, sandy gravel, silt, and clay of low-level terraces paralleling Potomac River estuary in Maryland (McCartan, 1989a, b). This report divides the Maryland Point Formation into two map units:

Qmp_1 — Fine to medium, poorly to moderately well sorted, light- to dark-gray sand, in part, clayey and silty. Constitutes surficial deposits of terraces ranging in altitude from sea level to about 6.5 m (21 ft). Base of unit commonly at or below sea level. On the basis of lithology and stratigraphic position, unit is equivalent to unit Qtlp (Lynnhaven and Poquoson Members of Tabb Formation, undivided) in Virginia

Qmp_2 — Fine to coarse, poorly to well-sorted, gray sand, weathers grayish orange. Beds of medium-gray to olive-gray silty clay in middle and lower parts of unit commonly contain abundant plant fragments. Beds of oysters (*Crassostrea virginica*) that crop out 1 to 3 m (3–10 ft) above sea level in river bluffs east and west of Maryland Point indicate a brackish-water depositional environment. Unit constitutes surficial deposits of extensive terrace (altitude 7.5 to 10 m (25–33 ft)) along Maryland side of Potomac River and is equivalent to Sedgefield Member of Tabb Formation in Virginia. Thickness is about 14 m (46 ft)

Qo — **Omar Formation (middle Pleistocene)**—Fine to medium gravel having coarse sand matrix in lower part of unit, grades upward to fine sand and sandy silt and clay; unit weathers yellowish gray to reddish brown. Underlies narrow remnants of a formerly extensive fluvial-estuarine terrace 12 to 15 m (39–49 ft) in altitude. Unit is equivalent to the Shirley and Chuckatuck Formations as mapped in Virginia. Thickness is as much as 15 m (49 ft)

Qcm — **Chicamuxen Church Formation (lower Pleistocene)**—Coarse gravelly sand and clay-silt grades upward to clayey and silty fine sand and silty clay; unit is light to medium gray; weathers to grayish yellow, yellowish orange, and brown. Unit underlies broad terrace in southwestern Charles County, Maryland; depositional surface is commonly 24 to 29 m (79–95 ft) in altitude. Unit is equivalent to the Charles City Formation in Virginia. Thickness is commonly 11 to 17 m (36–56 ft)

QTr — **Ravens Crest Formation (lower Pleistocene or upper Pliocene)**—Medium to coarse gravelly sand interbedded with fine to medium sand and clay; grades upward to fine silty sand and clayey silt; unit is light to dark gray; the finer sediments weather to pink, pale brown, and yellowish orange. Cobble- to boulder-sized clasts of gneiss, schist, red mudstone and sandstone, and quartzite are derived from Piedmont, Culpeper basin, Blue Ridge, and Valley and Ridge source areas. In map area, unit underlies depositional surfaces ranging in altitude from 30.5 m to about 35 m (100–115 ft). Unit was mapped as the Park Hall Formation by McCartan (1989a, b) but that name was found to be preempted (McCartan and others, 1996). On the basis of stratigraphic position and altitudes of depositional surfaces, the Ravens Crest is equivalent to the Windsor Formation in Virginia

Tug_4 — **Upland gravel 4 (upper Pliocene)**—Lower part of unit is poorly sorted, medium to very coarse gravelly sand, light- to medium-gray; oxidizes to grayish yellow and yellowish orange. Pebbles are mostly vein quartz, quartzite, sandstone, and chert. These coarse materials grade upward to fine silty sand interbedded with lenticular beds of silty clay and sandy silt, gray to pink. Underlies dissected upland surface (altitude 37 to 55 m (121–180 ft)) in Charles County, Maryland (see northern parts of Nanjemoy and Mathias Point 7.5-min quadrangles). On the basis of lithology, depth of weathering profiles, and stratigraphic position, unit is equivalent to the Bacons Castle Formation and, in part, to the Mooring unit of Oaks and Coch (1973). Thickness is as much as 21 m (69 ft)

Marine, Marginal-marine, and Fluvial-deltaic Deposits

Tps — **Sand and gravel (Pliocene)**—Interbedded yellowish-orange and reddish-brown gravelly sand, sandy gravel, and fine to coarse feldspathic sand, very poorly sorted to moderately well-sorted, commonly trough crossbedded; includes lesser amounts of clay and silt in thin to medium beds. Unit caps drainage divides (altitude 52 to 76 m (170–250 ft)) in western part of Coastal Plain where it conformably to unconformably overlies the marginal-marine facies of the Yorktown Formation. Westward, Unit Tps thins to a feather edge at the toe of the Thornburg scarp but equivalent fluvial deposits extend up the Rappahannock River and other Piedmont streams. Unit also includes the coarse clastic fill of the Bowling Green paleovalley. Thickness ranges from 0 to 18 m (0 to 60 ft)

Ty — **Yorktown Formation (upper and lower(?) Pliocene)**—Quartz and feldspar sand and sandy gravel, fine to very coarse, thin- to very thick bedded, planar and trough crossbedded, poorly to well-sorted; lesser amounts of clay and silt occur as matrix and as very thin to medium beds interbedded with coarser materials. Unit is commonly oxidized to yellowish gray, yellowish orange, and yellowish to reddish brown; where unweathered, strata are light to dark gray or bluish gray. Base of Yorktown is generally marked by a 0.1- to 4.6-m (0.3- to 15-ft)-thick bed of sandy gravel; clasts consist mainly of vein quartz, quartzite, and sandstone. Near margin of Coastal Plain in eastern Spotsylvania and western Caroline Counties, a conspicuous basal gravel includes abundant white to pale-gray, disk-shaped pebbles and small cobbles thought to indicate deposition along a strandline. The lower and middle parts of the Yorktown commonly include a distinctive, 2- to 5-m (7- to 16-ft)-thick, crossbedded to massive sand characterized by *Ophiomorpha nodosa* that is mappable over a wide area of the inner Coastal Plain. The *Ophiomorpha* beds and associated flaser- and lenticular-bedded fine sand, silt, and clay are believed to be shoreface and intertidal deposits recording an advance of the sea in the early late Pliocene. In the downdip, eastern parts of the map area, thin to thick layers of iron-oxide cemented sand, probably derived by weathering of sands rich in ilmenite and magnetite, are common. Along and east of Broad Rock scarp (see fig. 3; Mixon and others, 1994) at eastern edge of map area, the upper Yorktown has been removed by erosion and the lower part of unit is overlain unconformably by the Bacons Castle Formation. In the southeastern part of the map area, the Yorktown Formation unconformably overlies the Eastover Formation. North and west of Skinkers Neck anticline, the Yorktown laps over the Eastover onto diatomaceous strata of the upper Calvert Formation. At edge of Coastal Plain near Arcadia, Va., the Yorktown laps over the Calvert beds onto crystalline rocks of the outermost Piedmont. The Yorktown is typically 3 to 10 m (10–33 ft) thick but may be as much as 25 m (82 ft) thick in southeastern Caroline County where the formation includes three upward-fining sequences (Stop 5, Mixon and others, 1994)

Te — **Eastover Formation (upper Miocene)**—Very fine to fine quartzose sand, variably clayey and silty, thick- to very thick bedded, shelly in part, interbedded with very thin to thick-bedded sandy silt and clay. Scattered small fragments of wood are common. Where fresh, unit is dark gray to bluish gray and greenish gray; weathers to yellowish gray, greenish yellow, and yellowish brown. Molluscan fauna is dominated by the gastropod *Turritella plebia* and large bivalves including *Isognomon* sp., *Dallarca* sp., *Ostrea "compressirostra," Chesapecten middlesexensis, Placopecten principoides, Mercenaria* sp., and *Dosinia acetabulum*. The small bivalve *"Spisula" rappahannockensis*, an Eastover Formation guide fossil, was dominant in environments characterized by quiet, shallow-shelf waters and muddy substrates. An in situ whale skeleton in the Eastover Formation in the vicinity of Hustle, Va. (see Loretto 7.5-min quadrangle), was reported by Gilmore (1938). In the map area, unit is unconformable on the Calvert Formation; uneven basal contact with Calvert is marked by thin lag of fine to medium pebbles of quartz and phosphate. At edge of Coastal Plain just south of map area, unit laps over the Calvert onto Triassic beds of the early Mesozoic Taylorsville basin. The Eastover is sharply truncated by overlying Yorktown Formation along crest of Skinkers Neck anticline; unit is absent by truncation west of high. Thickness commonly 3 to 12 m (10–39 ft); unit is as much as 15 m (49 ft) thick in southeasternmost part of map area

Tms — **Sand and gravel (Miocene)**—Fine to coarse gravelly sand, sandy gravel, silt, and kaolinitic clay; unit is gray to light yellowish gray; commonly oxidized to yellowish orange and yellowish and reddish brown. Pebbles and cobbles are mainly quartz, quartzite, and crystalline rock and are commonly well rounded and deeply etched; crumbly in part. Unit commonly caps interfluve areas west of Thornburg scarp and constitutes the thin Coastal Plain outliers capping higher hills in easternmost Piedmont where deposits directly overlie crystalline rocks. Locally, 3 to 4 m (10–13 ft) of fine marine sand similar to the Calvert Formation are present between the crystalline rocks and unit Tms. Unit is as much as 10 m (33 ft) thick

Tc, Tcc, Tcp, Tcf — **Calvert Formation (middle and lower Miocene)**—Chiefly fine to very fine quartzose sand, variably silty and clayey, interbedded with diatomaceous silty clay and clayey silt; thick- to very thick bedded or massive; unit is medium to dark olive gray, grayish olive, and dark greenish gray; weathers light gray to white, pinkish gray, and pale yellowish orange. Locally, contains abundant external molds of marine mollusks. Map unit includes one to five sand-silt-clay sequences ranging in thickness from 2 to 12 m (7–39 ft). Each sequence consists of (1) a basal, very poorly sorted, very fine to coarse sand that commonly contains scattered pebbles of quartz and phosphate, fish teeth and scales, rare shell fragments, lignitized wood, and bones of marine vertebrates; grades upward to (2) clay and silt containing poorly to well-preserved diatom floras, silicoflagellates, and dinocysts; weathered sections are characterized by blocky fracture; grades upward to (3) very thick bedded, moderately well sorted to well-sorted, very fine sand.

Map unit includes, from bottom to top, the Fairhaven (Tcf), Plum Point Marl (Tcp), and Calvert Beach (Tcc) Members which are shown only in cross sections *A–A′* and *D–D′*. Beds containing *Rhaphoneis diamantella*, long considered a marker diatom for the Choptank Formation, are here tentatively included in uppermost part of the Calvert Beach Member. The Fairhaven Member occurs only in easternmost part of map area (cross section *A–A′*) where it is as much as 7 m (23 ft) thick in the vicinity of Popes Creek, Md., located adjacent to eastern side of map; the Fairhaven thins southwestward to 3 m (10 ft) in outcrops on Rappahannock River just south of Rollins Fork, Va., where it unconformably overlies the Nanjemoy Formation. Thickness of Calvert Formation ranges from 40 m (132 ft) in eastern part of area to a feather edge along western margin of Coastal Plain

Pamunkey Group

Tn, Tnw, Tnp — **Nanjemoy Formation (lower Eocene)**—Glauconitic quartz sand, fine to coarse, very clayey and silty, micaceous, shelly in part; contains abundant small concretions of iron sulphide; sand is interbedded with lesser amounts of silty and sandy clay. Fresh exposures are dark olive gray, greenish gray, and olive black; weathers yellowish brown. Map unit includes the Potapaco and Woodstock Members shown only in cross sections *A–A′* and *D–D′*. The upper part of the Nanjemoy (Woodstock Member, Tnw) is less clayey, very micaceous, very fine to medium glauconitic sand containing scattered fine quartz pebbles and abundant carbonaceous material. The lower Potapaco Member (Tnp) is very clayey and silty, very fine to fine glauconitic sand, commonly intensely bioturbated; includes some medium to coarse sand and a few thin, discontinuous beds of limestone. Thin-bedded, shelly sand dominated by the small bivalve *Venericardia potapacoensis* is characteristic of the lower Potapaco. The Nanjemoy Formation unconformably overlies the Marlboro Clay and, locally, where the Marlboro has been removed by erosion, the Aquia Formation. Formation thickness is as much as 64 m (210 ft)

Tmc — **Marlboro Clay (upper Paleocene)**—Kaolinitic silty clay and clayey silt, light- to dark-gray, light-brown, and pale-red to reddish-brown. Appears massively bedded, but cores and weathered outcrops show laminated to thin-bedded character of unit. Clay is commonly interbedded with lesser amounts of laminated and ripple-cross-laminated fine silt; small scour channels filled with sandy silt occur locally in updip areas. Rare molds of small mollusks, agglutinated foraminifers, a low diversity dinocyst assemblage, and the freshwater alga *Pseudoschizaea* indicate a brackish-water depositional environment. Gradational contact with underlying Aquia Formation commonly marked by interbedding, over a 0.5- to 1.0-m (2- to 3-ft)-thick interval, of thin beds of kaolinitic Marlboro Clay and fine sand of the Aquia Formation. Unconformable relation with overlying Nanjemoy Formation indicated by abrupt, uneven contact and by large, sand-filled burrows extending from base of Nanjemoy downward for 1 to 2 m (3–7 ft) or more into the Marlboro Clay. Sporomorph data from lower part of Marlboro indicate a late Paleocene age. Thickness ranges from less than one meter (3 ft) to about 9 m (30 ft). In Virginia, where unit is very thin, it is shown as a red line

Ta — **Aquia Formation (upper Paleocene)**—Glauconitic quartz sand, fine to medium, variably clayey and silty, thick- to very thick bedded or massive, sparsely to abundantly shelly. Commonly, sand is interbedded with a few thick- to very thick beds of sandy and shelly limestone; locally, in updip areas, silica replaces calcium carbonate as cementing material. Unit is light to dark olive gray, olive black, and greenish black; weathers to yellowish gray, grayish yellow, and grayish orange. The lower Aquia (Piscataway Member) is very clayey, fine to medium, poorly sorted sand containing scattered very fine pebbles; molluscan assemblage is dominated by large bivalves including *Cucullaea gigantea, Ostrea alepidota, Crassatellites* sp., and *Dosiniopsis* sp. In updip areas of Fredericksburg and Stafford 7.5-min quadrangles, unit is much less glauconitic and bedding is better defined. Black heavy-mineral cross-lamination, clay-lined burrows of the *Ophiomorpha* type, and small bars composed of clean, well-sorted, crossbedded sand indicate deposition in shoaling waters. The lower Aquia overlies the Lower Cretaceous Potomac Formation with pronounced unconformity and, in subsurface of south-central part of map area, laps across the Potomac onto crystalline basement rocks. Beds of the upper Aquia (Paspotansa Member) consist of very fine to fine, moderately well sorted, micaceous, thick-bedded to massive sand that is less clayey and less shelly than the lower Aquia; unit is characterized by thin layers of the large, high-spired gastropod *Turritella mortoni*; bivalves include *Ostrea sinuosa, Crassatellites alaeformis*, and *Cucullaea* sp. A late Paleocene (Thanetian) age for the Aquia Formation is based on foraminiferal, nannofossil, dinocyst, pollen, and molluscan assemblages. Formation thickness is as much as 35 m (115 ft)

Kp — **Potomac Formation (Lower Cretaceous)**—Includes three main sediment types. Type I consists of fine to coarse feldspathic quartz sand and sandstone, thick- to very thick bedded, trough crossbedded, poorly sorted; clay-silt matrix constitutes as much as 40 percent of sediment; commonly contains pebbles and cobbles of vein quartz, quartzite, and other metamorphic rocks. Outcrops are very light to medium gray or pinkish gray; core material may be greenish or bluish gray. Weathers brownish yellow, yellowish orange, and brown. Intraformational conglomerates containing pebble-sized clasts of clay and silt are common; locally, clay-silt boulders up to one meter (3 ft) in diameter suggest undercutting and caving of channel walls. Type I sediments are interpreted as channel-lag and channel-bar or point-bar deposits. Type II consists of silty and sandy clay, clayey silt, and clayey fine sand; unit is greenish gray, commonly mottled red or reddish brown; clay minerals are mainly illite and smectite. Commonly forms clay-silt plugs, 1 to 6 m (3–20 ft) thick and 2 to 20 m (7–66 ft) wide, within a dominantly medium to coarse sand sequence; clay plugs are believed to have been formed by filling of abandoned stream channels (cutoffs) by fine sediments during flood stages. Coalified stems of plants, as much as 30 cm (1 ft) in diameter, occur locally in types I and II; silicified trunks of large coniferous trees are present but rare. Type III consists of dark-yellowish-brown to olive-gray, lignitic sandy silt, clay, and silty fine sand and sandstone, flaggy in part; may contain well-preserved leaf and stem impressions of ferns and cycads and other gymnosperms. Occurrence as thin to thick beds associated with sediment type I suggests deposition in swales of point bars and (or) swampy areas of flood plains. Thickness of Potomac Formation ranges from a feather edge at western limit of outcrop to about 500 m (1640 ft) in the subsurface of the eastern part of the map area. Analysis of pollen and leaves from the Potomac beds in the map area indicate an Early Cretaceous (Barremian?, Aptian, and Albian) age for outcrop and subsurface sections

LOWER MESOZOIC ROCKS AND CENOZOIC SURFICIAL DEPOSITS OF THE CULPEPER BASIN

Surficial Deposits

Qal — **Alluvium (Holocene and Pleistocene)**—Gravel, sand, silt, and clay in lenticular layers underlying modern flood plains along streams; yellowish-brown to greenish-gray, fairly well bedded, poorly to moderately well sorted, graded deposits with gravel and sand commonly filling channels at base of upward-fining sequences. Most gravel clasts in streams draining the Piedmont highlands are subrounded greenstone, vein quartz, schist, phyllite, and other crystalline rocks; streams draining the Culpeper basin contain pebbles and cobbles of hornfels, sandstone, siltstone, greenstone, quartz, and diabase. Unit is as much as 6 m (20 ft) thick

QTt — **Terrace deposits (Pleistocene and (or) Pliocene)**—Gravel, sand, silt, and clay in fairly well bedded, gently sloping, graded deposits flanking principal rivers. Unit underlies discontinuous lowland benches about 6 to 20 m (20–66 ft) above the adjacent modern flood plains. Gravel is composed mainly of subrounded cobbles of weathered greenstone, vein quartz, quartzite, phyllite, hornfels, and diabase in a matrix of yellowish-orange to yellowish-brown silty clay. The lower contact is an unconformity; thickness ranges from a veneer to possibly as much as 10 m (33 ft); shown only where more than 3 m (10 ft) thick and 60 m (197 ft) wide

QTc — **Colluvium (Pleistocene and Pliocene)**—Gravel, sand, and silt in lenticular deposits on slopes and ridge tops adjacent to Piedmont highlands northwest and southeast of Culpeper basin and in "The Ridge." Unit consists of unsorted subangular clasts of greenstone, quartzite, vein quartz, schist, and phyllite in matrix of yellowish-orange to greenish-gray silty sand and clayey silt. Thickness ranges from a veneer to greater than 6 m (20 ft); basal contact is unconformable

Intrusive Rocks

Jdql, Jdqh, Jdqhg, Jd — **Diabase (Lower Jurassic)**—Unit Jdql is low-titanium diabase, light- to dark-gray, chiefly medium crystalline and porphyritic, but finely crystalline and aphanitic near chilled margins and in narrow dikes; in some areas, aphanitic diabase encloses light- and dark-gray, layered, orthopyroxene-rich cumulate; elsewhere, aphanitic diabase encloses light- and medium-gray, medium- to coarse-crystalline ferrogabbro, ferrodiorite, and pegmatoid, pinkish-gray to pale- and dark-pink porphyritic granophyre and syenite, and finely crystalline aplite. These low titanium diabases are magmatic derivatives of high-titanium, quartz-normative tholeiite (HTQ). Unit Jdqh is high-titanium diabase, mainly an interlocking crystalline mosaic of calcic plagioclase and pyroxene. Unit Jdqhg is predominantly late-stage granophyric differentiates containing sodic plagioclase, K-feldspar, quartz, hornblende, biotite, and pyroxene. Small pods of diabase of undetermined magma type (unit Jd) occur within the outcrop of thermally metamorphosed rocks surrounding the larger diabase intrusive bodies.

The most extensive occurrence of unit Jdqh is on the northern and eastern flanks of the Rapidan sheet, a very large and thick intrusive body composed mostly of cumulus bronzite, augite, and plagioclase. The Rapidan sheet is at least 360 m (1181 ft) thick in this area. The Germanna Bridge sheet, a related HTQ diabase, is a large northwest-dipping, northeast-trending sill-like body more than 150 m (492 ft) thick. Lower part of this sheet is fine- to medium-grained diabase; along southeastern flank, it contains sparse orthopyroxene (bronzite) crystals. Grades upward into medium-crystalline diabase enclosing pods of granophyric differentiates (Jdqhg) that locally form elongate hills. Along northwestern flank of sheet, the granophyric differentiates form a narrow, sinuous belt that locally thickens to broad, pod-like masses. A hornblende separated from syenite granophyre (sample GUP–84–1) yielded a nearly concordant $^{40}Ar/^{39}Ar$ age spectrum with a well-defined plateau age of 200.3±1.2 Ma (Sutter, 1988). This Early Jurassic age is interpreted to be a close approximation of time of igneous intrusion, differentiation, and crystallization of the Germanna Bridge sheet and related diabases (Sutter, 1988). A small HTQ sheet about 2.3 km (1.4 mi) wide is present north of Stevensburg, and chemically similar diabase occurs as small isolated pods and dikes.

Diabase of low-titanium (LTQ) magma type (Jdql), characterized by centimeter-sized clusters of calcic plagioclase phenocrysts, occurs as a poorly exposed, weathered, narrow, north-trending dike that forms spheroidal boulders along western side of "The Ridge," just east of Stevensburg

Thermally Metamorphosed Rocks

Trtm — **Hornfels, metagraywacke, and metaconglomerate (Upper Triassic)**—Dark-gray, greenish-gray to olive-black, bluish-gray and mauve, fine- to coarse-grained metasedimentary rocks occurring as zoned contact aureoles adjacent to diabase intrusions of Early Jurassic age; unit derived by thermal metamorphism of Upper Triassic siltstone, impure pebbly sandstone, and greenstone conglomerate. Cordierite-spotted hornfels is present at innermost part of aureole; epidote- and chlorite-rich hornfels, metagraywacke, and metaconglomerate characterize the remainder of the contact zone. Rocks of contact aureoles are generally hard, brittle, and resistant to weathering; bedrock is commonly at or near the ground surface. The contact aureole above and beneath the Rapidan sheet is about 120 m (394 ft) thick; the aureole enclosing the Germanna Bridge sheet is only about 60 m (197 ft) thick

Sedimentary Rocks

Trtmr — **Mountain Run Member of the Tibbstown Formation (Upper Triassic?)**—Pebble- to boulder-sized greenstone conglomerate and pebbly sandstone, interbedded in upward-fining, westward-coarsening sequences. Lower part of unit consists of angular to subangular clasts of yellowish-green metavolcanic rocks in an indurated, siliceous, dusky-red to pale-green, clayey sandstone and siltstone matrix. Upper part of unit contains more than 60 percent greenstone clasts and subordinate quartzite, feldspathic sandstone, and vein quartz clasts in an indurated sandstone or siltstone matrix. Fluvial cut and fill scours and pebble imbrication are common and well displayed at type section south and east of Culpeper (Lee and Froelich, 1989). Unit intertongues to the east with dark-red and grayish-red, coarse- to fine-grained, feldspathic sandstone and siltstone lenses of lacustrine member of Balls Bluff Siltstone. The Mountain Run Member ranges in thickness from a feather edge to the east, to an estimated 640 m (2100 ft) on western flank of basin near Culpeper (Lee and Froelich, 1989). The upper contact relations are unknown as erosion has removed overlying beds. A tentative age of Late Triassic is based on intertonguing relation with the dated Balls Bluff Siltstone

Balls Bluff Siltstone (Upper Triassic)

Trbl — Lacustrine member—Siltstone, mudstone, and shale, interbedded in upward-fining cyclic sequences. Siltstone is dusky red to reddish brown and tan, sandy, micaceous, contains mudstone lenses, desiccation cracks, root tubes, and vugs. Mudstone is dark gray to black, light gray to purple, massive to laminated, locally silty or sandy; contains oscillation ripples and polygonal mud cracks, dinosaur and other reptile trackways, sparse shelly fossils, and common root tubes, vugs, and soil fabric. Locally, mudstone is calcareous and dolomitic and may contain thin beds of oolitic and stromatolitic limestone. The more conspicuous beds of gray to black mudstone are shown by dashed red lines. Sulfides of iron, copper, zinc, and lead are present in small amounts. Sporomorphs from gray mudstones suggest a Late Triassic age (R.J. Litwin, oral commun., 1991). Thickness of lacustrine part of Balls Bluff Siltstone probably exceeds 1000 m (3280 ft)

Trbf — Fluvial member—Siltstone, sandstone, and shale, interbedded in upward-fining sequences. Siltstone is dusky red to reddish brown and dark red, sandy, micaceous, in part calcareous with carbonate nodules (caliche), locally has climbing-ripple cross lamination. Unit is generally hard and brittle, especially near thermal aureoles, and has hackly fracture. Commonly, lower part of unit is interlayered with thin, very fine grained, impure sandstone; grades upward into silty shale, dark-red to reddish-brown, with ripple laminations and dessication features. Unit is generally poorly exposed and deeply weathered. As no fossils have been found, unit is inferred to be Late Triassic in age based on stratigraphic position. Thickness in map area is estimated to be 100 to 200 m (328–656 ft); both upper and lower boundaries are gradational

Manassas Sandstone (Upper Triassic)

Trmu — Upper unnamed member—Sandstone, pebbly sandstone, siltstone, and minor shale, interbedded in upward-fining sequences. Sandstone is dark greenish gray, pinkish gray, grayish red, fairly well to poorly sorted, locally crossbedded; mainly a fine- to coarse-grained lithic arenite with less than 10 percent quartz grains, abundant feldspar, chlorite, epidote, and comminuted rock fragments in a pasty matrix of reddish-brown ferruginous clayey silt or greenish-gray chloritic clay and silt. Commonly, these impure sandstones become finer grained upward and grade into siltstone, reddish-brown to dusky-red and dark-red, sandy, micaceous, calcareous, and nodular, in part; locally has climbing-ripple cross lamination; generally hard and brittle, with hackly fracture. Unit overlies the Rapidan Member conformably and intertongues with and is overlain conformably and gradationally by Balls Bluff Siltstone. Unit is generally very poorly exposed and deeply weathered to saprolite except where thermally metamorphosed. Thickness in map area ranges from about 200 to 300 m (656–984 ft). As no fossils have been found in this predominantly fluvial unit, the age is inferred to be Late Triassic based on its stratigraphic position

Trmr — Rapidan Member—Conglomerate, sandstone, and minor siltstone, interbedded in upward-fining sequences. Conglomerate is mainly dark greenish gray, containing subangular to rounded boulders, cobbles, and pebbles of grayish-olive-green metabasalt (Late Proterozoic Catoctin Formation) and minor fragments of quartzite, meta-arkose, vein quartz, marble (Everona Limestone?), and phyllitic schist in a pasty matrix of greenish-gray, clayey quartz granules and silt cemented by silica or calcite. Sandstone is mainly a lithic arenite (graywacke), dark-greenish-gray, pinkish-gray, grayish-red and dark-red, fairly well to poorly sorted, locally contains greenstone pebbles in a dark-gray silt and clay matrix. In lower part of unit, lensoid bodies of sandstone and conglomerate fill fluvial channels. In upper part of unit, dark-red sandstone fines upward to siltstone, red-brown to dusky-red, sandy, micaceous, in part calcareous, brittle, having hackly fracture. Near the western edge of the map area, between the Long Branch and Raccoon Branch tributaries of the Rapidan River, the Rapidan Member unconformably overlies the Catoctin Formation. Farther to the northeast along the edge of the Culpeper basin, and north of the community of True Blue, the Rapidan Member unconformably overlies or is in fault contact with slate, siltstone, and argillite of the True Blue Formation. In this area, the Rapidan intertongues with and is conformably overlain by impure sandstone and siltstone of the upper member of the Manassas Sandstone. As no fossils are known in the Rapidan Member, it is inferred to be Late Triassic based on stratigraphic position. Thickness of the Rapidan Member ranges from a feather edge to 140 m (459 ft) where best exposed at type section on the Rapidan River about 5.5 km (3.5 mi) east-northeast of Raccoon Ford (Measured Section 1, Appendix A, Lee and Froelich, 1989)

POST-PALEOZOIC ROCKS OF THE PIEDMONT

Jd — **Diabase dikes (Jurassic)**—Crystalline, medium- to fine-grained, dark-gray to black, generally intergranular to ophitic textured diabase rocks. Predominantly bytownite-augite diabases with opaques and locally minor biotite as common accessory. Less common diabase contains fayalitic olivine with bytownite more calcic than olivine-free diabase

PALEOZOIC AND PROTEROZOIC ROCKS OF THE PIEDMONT

Metasedimentary and Metavolcanic Rocks

Continental-margin terrane

O€te, O€t — **True Blue Formation (Ordovician and (or) Cambrian[1])**—Calcareous and noncalcareous slate and siltstone and lesser amounts of argillite. Includes large, lenticular bodies of the Everona Limestone Member (O€te) (Pavlides, 1987, 1994), which commonly consist of gray-blue, fine-grained, thin-bedded and finely laminated, silty to nearly pure metalimestone; maximum thickness is about 160 m (525 ft). Minor amounts of chert and ironstone are present locally

Zc — **Catoctin Formation (Late Proterozoic)**—Greenstone, green phyllitic tuff, and fragmental greenschist rocks (brecciated pillows?)

Back-arc basin terrane (mélange deposits)

Mine Run Complex (Ordovician and (or) Cambrian)—The four thrust slices of block-in-phyllite mélange that compose the Mine Run Complex are numbered from east to west (I–IV). In fresh outcrop, the matrix rocks of the four mélange zones are various shades of gray or green, and many of the matrix rocks are metagraywackes

O€mIV, O€mIVq, O€mIVv — Mélange zone IV—Gray-green and green phyllite, metasandstone, and metasiltstone. Unit includes a large lenticular body of metavolcanic and metavolcaniclastic phyllite (O€mIVv), which grades westward into mostly fine-grained metasandstone and metasiltstone (O€mIVq). O€mIVv and O€mIVq are bounded on the west by the Mountain Run fault zone. The metasandstone of O€mIVq grades into and becomes indistinguishable from phyllonite and mylonite of the Mountain Run fault zone. Exotic blocks are absent in mélange zone IV within the map area but are present along strike to the southwest

O€mIII — Mélange zone III—Phyllite and schist matrix with abundant euhedral magnetite. This magnetite invariably crosscuts rock foliation and is a late metamorphic mineral. Many matrix rocks are highly deformed on a mesoscopic and microscopic scale and enclose exotic Late Proterozoic and (or) Cambrian blocks of amphibolite (€Za), ultramafic rocks (€Zu), biotite gneiss (€Zbg), granite gneiss (€Zgg), serpentinite (€Zs), and massive as well as foliated talc (€Zt). Many exotic blocks are composite and represent various combinations of serpentinite and talc (€Zst), amphibolite and serpentinite (€Zas), amphibolite and talc (€Zat), and serpentinite and mafic rock (€Zsm). Felsic metavolcanic blocks (€vf) possibly derived from the Chopawamsic Formation are rare olistoliths. Mafic metavolcanic blocks (€vm) also are present but too small to map

O€mII — Mélange zone II—A thrust slice containing Cambrian(?) felsic (€vf) and mafic (€vm) metavolcanic blocks similar to those found in the Chopawamsic Formation; unit also contains Cambrian(?) granitoid blocks of altered tonalite and granodiorite (€tg). The mélange matrix, which consists of schist and phyllite, generally has crenulation cleavage, indicating that matrix rocks of mélange zone II are more highly deformed than those of mélange zone I

O€mI — Mélange zone I—Matrix rocks of fine-grained schist and phyllite locally enclose coarse-grained metasandstone beds. Unit includes exotic blocks of felsic (€vf) and mafic (€vm) metavolcanic rocks similar to metavolcanic rocks of the Chopawamsic Formation (€c). Blocks of blastomylonitic tonalite and granodiorite gneiss (€Zgn) are present in two separate blocks to the south-southeast of Mine Run

O€l — **Lunga Reservoir Formation (Ordovician and (or) Cambrian)**—Diamictite-type mélange consists of nonstratified, micaceous, quartzo-feldspathic rock (metagraywacke) containing granule- to pebble-sized quartz lumps and, less commonly, boulders of quartz. Chips and pebbles of gneiss and schist, some having an internal foliation athwart that of the enclosing rock, also are present. The metagraywacke, quartz lumps, and schist and gneiss chips are the matrix that encloses exotic blocks of greenstone and metamafic rock derived, in part, from the Chopawamsic Formation

Successor basins terrane

Ou — **Metasedimentary rocks, undivided (Ordovician)**—Gray to green silty phyllite, gray to white metasiltstone and fine-grained quartzite, fine-grained mica schist or semi-schist, green schist and phyllite and sparse granule quartzite and metagraywacke layers

Op, Opm — **Phyllite (Ordovician)**—Mostly gray to green phyllite and lesser amounts of metasiltstone. Mylonitic rock (Opm) composed of semi-schist and phyllite having elongate granules of quartz is interpreted as a highly sheared part of the phyllite unit (Op). Alternatively, the mylonitic rock may be part of a separate, older terrane

Oq, Oqq — **Quantico Formation (Upper Ordovician)**—Dark-gray phyllite and micaceous, fine- to medium-grained staurolite schist and biotite-muscovite garnetiferous schist that locally contains kyanite. Calc-silicate layers are present locally. Quartzite (Oqq) forms thin discontinuous lenses within the formation and, locally, at its base

Island-arc terrane

€c — **Chopawamsic Formation (Cambrian)**—Consists of lenses and tongues of metavolcanic and metasedimentary rocks; individual units do not have great lateral extent. Metavolcanic rocks include silicic, intermediate, and mafic varieties, some of which probably were flows, as suggested by their highly vesicular character. Fragmental rocks are mainly breccia and tuff. Fine-grained feldspathic schist and phyllite without identifiable fragments are mineralogically and chemically similar to the more distinctive volcanic rocks and may be tuffaceous. Schist, meta-arenite, and locally, amphibole-free gneiss of probable sedimentary origin are interlayered with the metavolcanic rocks; the proportion of metasedimentary rocks varies from place to place along the formation. Silicic metavolcanic rock typically is light gray; some varieties have small phenocrysts of quartz and (or) feldspar. Some felsic metavolcanic rocks contain albitic plagioclase and quartz in a finer grained, quartzofeldspathic groundmass and are keratophyres. Intermediate metavolcanic rocks are dark to light green and commonly have a nematoblastic groundmass texture formed by aligned prismatic amphibole intergrown with fine-grained quartz and feldspar. Mafic rocks of the Chopawamsic Formation include amphibolite greenstone and various dark schists

€t — **Ta River Metamorphic Suite (Cambrian)**—Dark-gray to black, well-foliated amphibolitic gneisses that are rarely layered. Gneiss ranges from amphibolite through various types of amphibolite gneiss to biotite gneiss. In the northern part of the outcrop belt, the Ta River is chiefly amphibolite gneiss associated with conformable granitoid rocks and smaller amounts of biotite gneiss and schist. Along strike to the southwest, the Ta River contains more biotite gneiss and schist and smaller amounts of amphibolite gneiss. An increase in regional metamorphic grade also occurs in the southwestern part of the Ta River Metamorphic Suite, and associated granitoid bodies are more felsic than in the northeastern part of the Ta River. Some amphibolite in the southern part of the outcrop belt contains pyroxene, which may reflect higher grade regional metamorphism here than in the Ta River terrane to the northeast

Salem Church allochthon

€Zh — **Holly Corner Gneiss (Cambrian or Late Proterozoic)**—Dark-gray to black, fine- to medium-grained, well-foliated hornblende- and biotite-rich gneiss. Compositional layering is rare; where present, it generally consists of thin calc-silicate layers of quartz, andesine, epidote, and diopside. Typically, the Holly Corner is an amphibole gneiss containing varying amounts of biotite. Locally, biotite is the dominant dark mineral

Oqq — **Quartzite beds of the Quantico Formation (Upper Ordovician)**—West of Fredericksburg, at the downstream end of Motts Run reservoir, thin, discontinuous lenses of impure quartzite occur along the north-trending contact between the Holly Corner Gneiss and the Quantico Formation. These beds are tentatively interpreted to be a distal part of the basal quartzite of the Quantico that was deposited upon the Holly Corner Gneiss prior to its westward transport and incorporation into the nappe forming the Salem Church allochthon (see discussion in text)

Sf — **Falls Run Granite Gneiss of the Berea pluton (Silurian)**—Pale-pink to nearly white, coarse-grained, strongly foliated hornblende and biotite granitic gneiss ranging in composition from monzonite to granite

Matta nappe

PzZp, PzZpm, PzZpa, PzZpmb — **Po River Metamorphic Suite (lower Paleozoic and (or) Late Proterozoic)**—Biotite gneiss and schist; the most common lithology is biotite gneiss. Characteristically the gneiss is a dark-colored, layered, and foliated rock; micaceous materials are concentrated in the dark layers, and quartz and feldspar are concentrated in the light layers. However, all gradations in the relative proportions of mica, quartz, and feldspar are found in the various layers that constitute the gneiss. Feldspar occurs both as a groundmass constituent and, very commonly, as large augen-shaped grains. Hornblende-bearing gneiss also is present in subordinate amounts as compared with the biotite gneiss. It resembles the biotite gneiss in color and texture but contains varying amounts of hornblende, as well as biotite. Garnetiferous two-mica schist is found locally and has a foliation conformable with the adjacent gneisses.

Many foliated gneissic granitoid rocks, including pegmatoids, occur in tabular bodies as well as nontabular masses in the Po River terrane. The tabular granitoid and pegmatoid bodies form concordant, sill-like layers that range from less than 2.5 cm (0.8 in) to as much as 7.6 m (25 ft) wide. Locally, thinner granitoid layers about 0.5 to 1.0 cm (0.2–0.3 in) wide are conformable with the foliation in the gneiss. The nontabular, irregularly shaped granitoid bodies generally form relatively large masses that may be parts of plugs and plutons of various sizes.

In the southern part of the outcrop of the Po River Metamorphic Suite, several lenticular units can be distinguished. PzZpm is a fine- to coarse-grained, strongly foliated, strongly layered (0.5 cm–0.3 m (0.2 in–13 in)) garnet-muscovite quartzofeldspathic gneiss; locally it grades into biotite gneiss. PzZpa is a fine- to coarse-grained, weakly to strongly foliated, irregularly layered amphibolite and amphibole gneiss; unit occurs at different horizons in the Po River Metamorphic Suite. PzZpmb is a quartz-rich, magnetite-bearing biotite gneiss that generally also contains muscovite and garnet and has a wide range in grain size

PzZph — **Biotite-hornblende gneiss (lower Paleozoic or Late Proterozoic)**—Coarse-grained, moderately to strongly foliated, weakly layered epidote-microcline-biotite-hornblende-quartz-plagioclase gneiss with discontinuous layers of biotite gneiss and granitic biotite gneiss. Many lenticular or tabular, concordant to discordant inclusions of fine-grained, foliated amphibolite range in length from a few centimeters to about 2 m (7 ft)

Intrusive Rocks

Cf — **Falmouth Intrusive Suite (Carboniferous)**—Fine-grained monzogranite and pegmatitic granite, fine-grained granodiorite and, less commonly, tonalite

Sf — **Falls Run Granite Gneiss (Silurian)**—Pale-pink to nearly white, coarse-grained, strongly foliated hornblende and biotite granitic gneiss ranging in composition from monzonite to granite

S€i, SOe — **Biotite granodiorite of the Ellisville pluton (Silurian or Ordovician)**—Composed almost exclusively of biotite granodiorite that typically is coarse to medium grained, mostly mesocratic, equigranular to porphyritic in texture, and massive to strongly foliated. Contains granitoid intrusions or inclusions of Cambrian and Silurian age (S€i) and a Late Proterozoic to Cambrian amphibolitic xenolith (€Za)

SOg — **Muscovite-biotite granite (Silurian or Ordovician)**—Dark-gray granite with mosaic-textured quartz and with abundant microcline and minor sodic plagioclase; intrusive into the Garrisonville Mafic Complex (€Zg)

Lahore pluton of the Lahore Complex (Ordovician)

Olg — Amphibole-bearing shoshonitic monzonite—Mesocratic, medium-grained, foliated granitoid composed of amphibole monzonite and minor amounts of amphibole quartz monzonite

Ola — Pyroxene-bearing shoshonitic monzonite—Composed of massive, fine- to medium-grained melanocratic biotite-andesine-augite monzonite that grades into amphibole monzonite

Olm — **Mafic pluton of the Lahore Complex (Ordovician)**—Partially serpentinized pyroxenite consisting of well-formed diopside rimmed by antigorite and amphibole; diopside metapyroxenite is present as a medium-grained rock with cores of diopside replaced by tremolite on margins

Og — **Metamonzogranite of Goldvein pluton (Ordovician)**—Coarse- to medium-grained, mesocratic, weakly to strongly foliated metamonzogranite. Altered pink and green feldspars occur locally

O€tj — **Trondhjemite of the Horsepen Run pluton (Ordovician and (or) Cambrian)**—Allotriomorphic granular, fine-grained rock locally having granophyric texture of intergrown albite and quartz. Blue-green amphibole is locally abundant, and garnet is present at many places

O€pg — **Plagiogranite of the Richland Run pluton (Ordovician and (or) Cambrian)**—Plagiogranites and related rocks, predominantly tonalite; normally leucocratic to mesocratic quartz-rich meta-intrusive rocks. Typically plagioclase-rich, having minor or no potassic feldspar. Unit has undergone cataclasis to varying degrees and, locally, is protomylonitic to mylonitic. Plagiogranite is locally intruded by mafic dikes

€g — **Amphibole metagabbro (Cambrian?)**—Coarse- to medium-grained, melanocratic. Where unit intrudes the Chopawamsic Formation (€c), it is massive as well as foliated and is cut by numerous mafic dikes not shown on the map. Where the metagabbro intrudes the amphibolite-grade Ta River Metamorphic Suite, it consists of coarse-grained amphibole and altered plagioclase in a groundmass of fine-grained plagioclase and quartz. Epidote is generally abundant

€Zg — **Garrisonville Mafic Complex (Lower Cambrian or Late Proterozoic)**—Fine- to coarse-grained, melanocratic, massive to foliated metamafic rocks. Chiefly amphibolite and hornblendite. In western part of complex, contains lesser amounts of enstatite-bearing metapyroxenite, metawebsterite, and metanorite. Metamorphic alteration is less intense in western part of complex. At western edge of complex, talc-amphibole schist occurs near the contact with country rock

PzZd — **Diorite gneiss of the Potomac Creek pluton (lower Paleozoic or Proterozoic)**—Gray, fine- to medium-grained, well-foliated and highly lineated, quartz-plagioclase-biotite gneiss containing abundant well-formed accessory epidote and, locally, sparse garnet and minor amounts of muscovite. Locally, unit grades into granodiorite. Dikes of foliated metamonzogranite commonly intrude the gneiss

PzZpg — **Granitic gneiss (lower Paleozoic or Proterozoic)**—Fine- to medium-grained, streaky granitic gneiss. Ranges modally between granite and tonalite. Intimately interlayered with and contains inclusions of biotite gneiss, biotite schist, and amphibolite of the Po River Metamorphic Suite. Occurs as irregular tabular or lenticular masses

LOWER PALEOZOIC? AND LATE PROTEROZOIC ROCKS OF BLUE RIDGE AFFINITIES

The Ridge

€m — **Metasedimentary rocks, undivided (Lower Cambrian?)**—Tan, gray, and light-brown, fine- to coarse-grained, pebbly feldspathic quartzite interbedded with tan and bluish-purple laminated metasiltstone and phyllite. Poorly sorted, crossbedded, and has pervasive slaty cleavage. Unit forms "The Ridge," a north-trending, fault-bounded inlier of metamorphic rock in the Culpeper basin, just east of Stevensburg. Overlies the Catoctin Formation; contact is not exposed. Unit may correlate with the Nasons Formation mapped west of map area in Orange County, Virginia (Pavlides, 1994). Thickness not known because of poor exposure and minor folding

Zc — **Catoctin Formation (Late Proterozoic)**—Dark-green, aphanitic to medium-grained massive metabasalt (greenstone); locally interbedded with thin phyllite and quartzite. Greenstone has a strong foliation that is coplanar to slaty cleavage in adjacent metasedimentary rocks; thickness unknown due to poor exposure

Blue Ridge anticlinorium (east limb)

Zc — **Catoctin Formation (Late Proterozoic)**—Dark-green, aphanitic to medium-grained massive metabasalt (greenstone); locally interbedded with thin phyllite and quartzite. Greenstone has a strong foliation that is coplanar to slaty cleavage in adjacent metasedimentary rocks; thickness unknown due to poor exposure

Zch — **Charlottesville Formation of the Lynchburg Group (Late Proterozoic)**—Micaceous metasiltstone to massive quartz-muscovite-sericite schist interbedded with thin quartzite and dark-greenish-brown meta-arkose layers; unit commonly deeply weathered to light-brown and light-gray clay and sandy clay with phyllitic luster

[1]The U.S. Geological Survey has accepted the Cambrian-Proterozoic boundary as being at about 570 million years ago in the standard geologic time scale. Recently, however, uranium-lead zircon chronology of volcanic rocks, interlayered within a sequence of paleontologically well established Cambrian rocks in Siberia, suggests that the Cambrian-Proterozoic boundary is better placed at about 544 million years ago (Bowring and others, 1993). Thus, the ages and tectonic events related to rocks older than 544 million years as described in this report may have different temporal settings than those described herein.

EXPLANATION OF MAP SYMBOLS

- **Contact**—Dashed where inferred; dotted where concealed
- **Isograd or limit of thermal aureole**—Ticks point to higher grade facies

FAULTS IN THE PIEDMONT AND THE CULPEPER BASIN

- **Fault**—Sense of displacement not known; dotted where concealed
- **High-angle fault**—Dashed where inferred; dotted where concealed; U, upthrown side; D, downthrown side
- **Strike-slip fault**—Arrows show relative movement; dotted where concealed
- **Thrust fault**—Sawteeth on upper plate; arrows show inferred post-thrust strike-slip movement; dotted where concealed
- **Overturned thrust fault**—Base of sawteeth on upper plate. Sawteeth indicate direction of dip; dip given where known. Dotted where concealed
- **Limits of rock types that define the Mountain Run fault zone**—These rocks include phyllonite, mylonite, breccia, and phyllite with fish-scale or button-schist structure

FAULTS IN THE COASTAL PLAIN

- **High-angle reverse or vertical fault, showing dip**—Dashed where inferred; dotted where concealed

FOLDS IN THE PIEDMONT

(Showing axial trace, direction of dip of limbs and plunge direction, where known or inferred; dotted where concealed)

Bedding folds—Defined on the basis of bedding
- Anticline
- Syncline

Foliation folds—Foliation may be parallel to bedding and (or) compositional layering

Early folds
- Antiform
- Synform
- Overturned antiform
- Overturned synform

Late folds that fold earlier foliation folds
- Antiform
- Synform
- Minor overturned anticline

FOLDS IN THE COASTAL PLAIN

- **Axial trace of the Skinkers Neck anticline**—Showing plunge and bifurcation. Affects mainly middle Eocene and older strata

PLANAR FEATURES

(May be combined with linear features)

Strike and dip of bedding
- Inclined
- Vertical

Strike and dip of compositional layering
- Inclined
- Vertical

Strike and dip of cleavage
- Inclined
- Vertical

Strike and dip of joints—Two or more sets shown at point of intersection
- Inclined
- Vertical

Strike and dip of phyllitic foliation—Includes semi-schistosity and transposition; anastamosing and continuous foliation may be combined with mineral lineation symbol
- Inclined
- Vertical

Strike and dip of shear foliation
- Inclined
- Vertical

Strike of bedding parallel to phyllitic foliation

Strike of vertical compositional layering parallel to phyllitic foliation

Strike and dip of early schistosity
- Inclined
- Vertical
- Overturned
- Crenulated

Strike of vertical late schistosity

Strike and dip of magmatic flow foliation
- Inclined
- Vertical

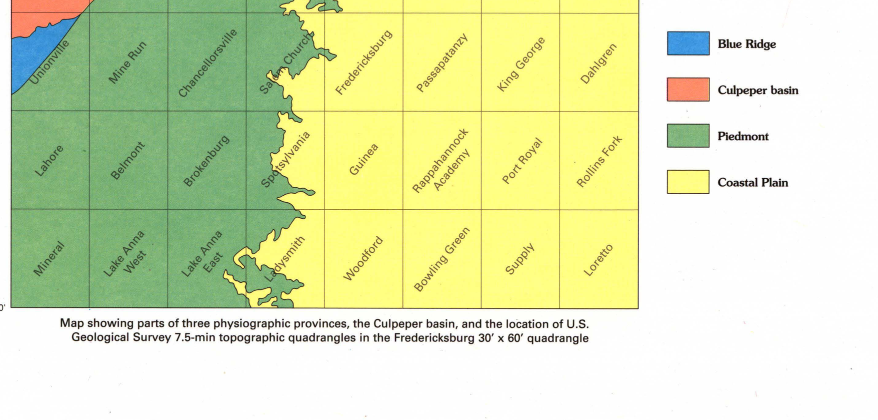
LINEAR FEATURES

(May be combined with planar features)

- **Bearing and plunge of early mineral lineation**
- **Bearing and plunge of late mineral lineation**

OTHER SYMBOLS

- **Stratigraphic test well coring Triassic rock**
- **U.S. Geological Survey corehole**
- **U.S. Geological Survey auger hole**
- **Oil and gas test well**
- **Water well**—G, geophysical log; L, lithic log; TD=Total depth
- **Outcrop or trench exposing a fault**—Number keyed to table 1 in pamphlet. Consult table for detailed description of faults
- **Type section of a formation or member**—A, Aquia Formation; W, Woodstock Member of the Nanjemoy Formation; M, Mountain Run Member of the Tibbstown Formation; R, Rapidan Member of the Manassas Formation
- **Triassic palynomorph locality**
- **Radiometric age determination of granophyric diabase (Sutter and others, 1985)**
- **Active quarry with dinosaur trackways**
- **Abandoned quarry**
- **Site of photograph**—Tip of arrow at point of observation; arrow shows direction of view; number keyed to figure on sheet 2



Map showing parts of three physiographic provinces, the Culpeper basin, and the location of U.S. Geological Survey 7.5-min topographic quadrangles in the Fredericksburg 30′ x 60′ quadrangle

GEOLOGIC MAP OF THE FREDERICKSBURG 30′ x 60′ QUADRANGLE, VIRGINIA AND MARYLAND

By

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