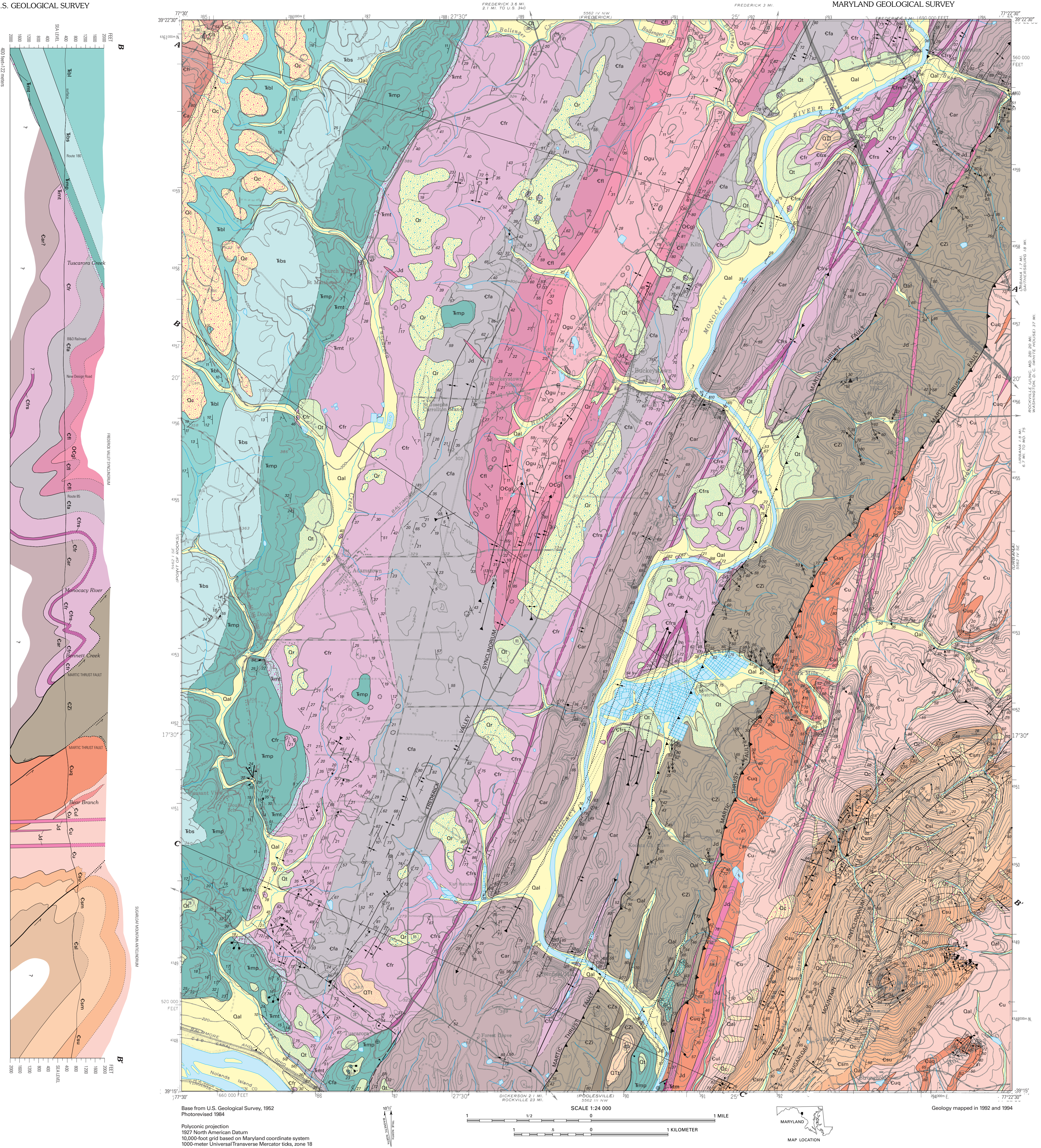
U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

Prepared in cooperation with the
MARYLAND GEOLOGICAL SURVEY

GEOLOGIC QUADRANGLE MAP
BUCKEYSTOWN QUADRANGLE, MARYLAND AND VIRGINIA
MAP GQ–1800

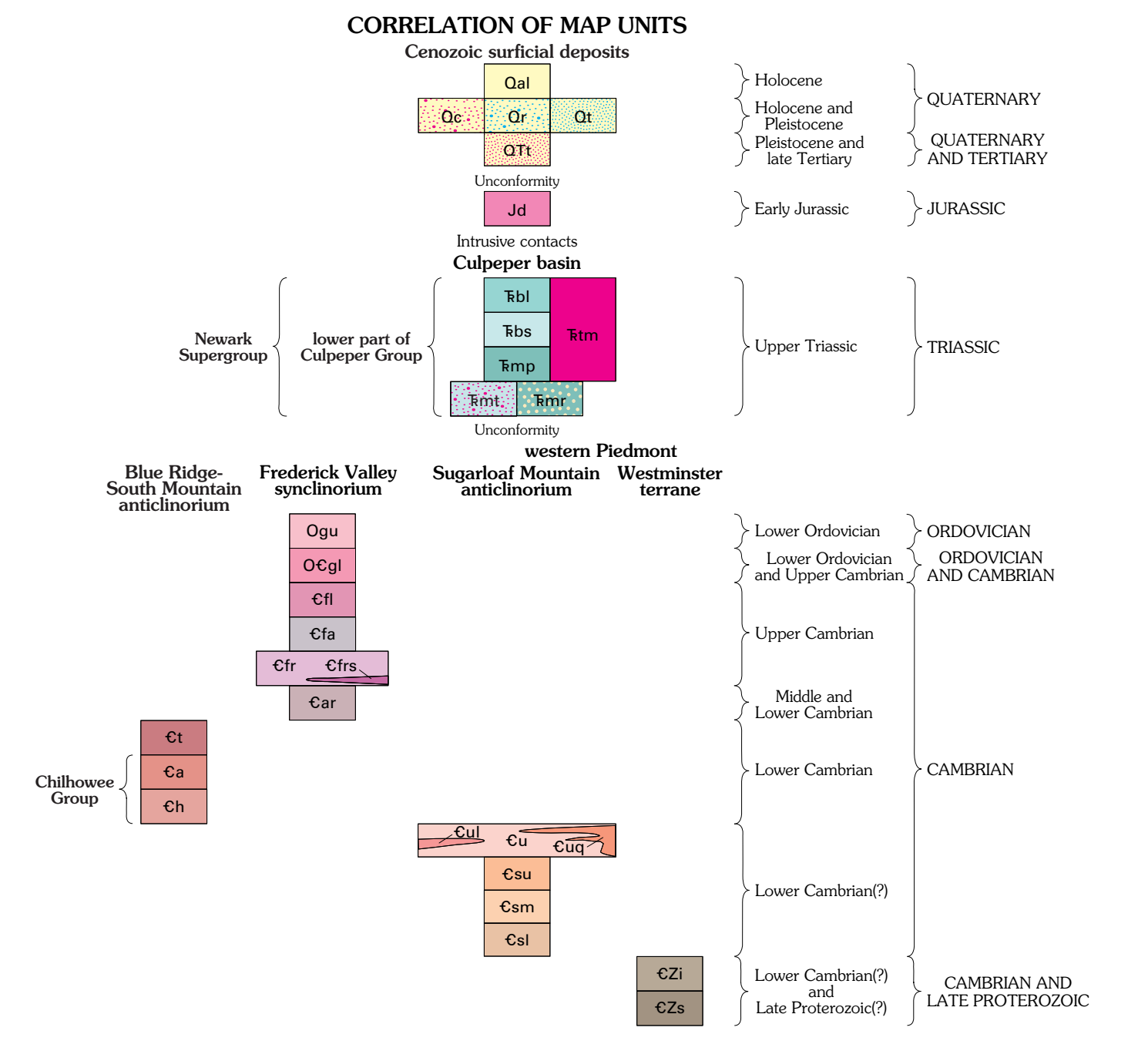


Base from U.S. Geological Survey, 1982
Photorevised 1986
Polyconic projection
1927 North American Datum
10,000-foot grid based on Maryland coordinate system
1000-meter Universal Transverse Mercator ticks, zone 18

CONTOUR INTERVAL 20 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

Geology mapped in 1992 and 1994

CORRELATION OF MAP UNITS



DESCRIPTION OF MAP UNITS

[Color designations, in parentheses, are from Goddard and others (1948)]

CENOZOIC SURFICIAL DEPOSITS

Qal **Alluvium (Holocene)**—Unconsolidated mixture of clay, silt, sand, gravel, cobbles, and some boulders underlying flood plains of Potomac and Monocacy Rivers and their tributaries. Includes alluvial terraces as much as 10 ft above stream channels, and fine colluvial debris from adjacent slopes. Sediments well to poorly stratified, commonly in fining-upward sequences as much as 20 ft thick

Qc **Colluvium (Holocene and Pleistocene)**—Coarse cobbles, boulders, and blocks of quartzite that were transported by gravity and debris flow, and subsequently modified by freezing and thawing. Concentrated in hillslope depressions and hollows on Sugarloaf Mountain. Thickness ranges from thin veneer to greater than 10 ft. Includes subangular to subrounded pebbles and cobbles of quartzite and vein quartz derived from rocks of Blue Ridge-South Mountain anticlinorium in fan-like aprons covering strata along western margin of Culpeper basin. Thickness ranges from thin veneer to 3 ft

Qr **Residuum (Holocene and Pleistocene)**—Unconsolidated mixture of moderate reddish brown (10 R 4/6) soil, pebbles, and blocks of grayish pink (5 R 8/2) to white (N9) angular, locally euhedral quartz derived from in-place weathering of underlying carbonate rocks. Thickness ranges from thin veneer to 10 ft

Qt **Terrace deposits (lowest level) (Holocene and Pleistocene)**—Sand, gravel, and boulder deposits 10 to 20 ft thick underlying nearly flat benches that are 33 to 80 ft above Potomac and Monocacy Rivers

QTt **Terrace deposits (highest level) (Pleistocene and late Tertiary)**—Gravel and boulder deposits on isolated hillocks as much as 183 ft and 140 ft above Potomac and Monocacy Rivers. Clasts of predominantly quartzite with *Skolithos* (trace fossil) have thick weathering rinds

INTRUSIVE ROCKS

Jd **Diabase dikes (Early Jurassic)**—Medium (N5)- to dark-gray (N3), moderately to coarsely crystalline, equigranular, massive diabase with characteristic light-brown (5 YR 5/6) weathered surface. Discontinuous and en echelon subvertical tabular bodies

SEDIMENTARY ROCKS OF THE CULPEPER BASIN

TRtm **Thermally metamorphosed rocks (Upper Triassic)**—Dark-gray (N3) to olive-black (5 Y 2/1) cordierite-spotted hornfels in zoned contact aureole adjacent to diabase dike at Monocacy Natural Resources Area

Balls Bluff Siltstone (Upper Triassic)

TRbl Leesburg Member—Light-gray-weathering carbonate conglomerate with subangular to subrounded boulders, cobbles, and pebbles of grayish and reddish lower Paleozoic limestone and dolomite in reddish-brown pebbly sandstone and calcareous siltstone matrix

TRbs Fluvial sandstone and siltstone member—Dark-reddish-brown (10 R 3/4), fine- to medium-grained, thin- to medium-bedded, locally crossbedded, feldspathic, silty sandstone interbedded with dusky-red (5 R 3/4), thin-bedded, bioturbated, calcareous, micaceous, feldspathic, clayey and sandy siltstone in repetitive sequences 3 to 10 ft thick. Grades down into Poolesville Member of Manassas Sandstone (TRmp) and intertongues laterally with Leesburg Member (TRbl). Composite thickness estimated to exceed 5,000 ft

Manassas Sandstone (Upper Triassic)

TRmp Poolesville Member—Predominantly medium-gray (N5), pinkish-gray (5 YR 8/1), and pale-reddish-brown (10 R 5/4), fine- to coarse-grained, thick-bedded, arkosic and micaceous sandstone; locally pebbly and crossbedded where it fills channels; commonly interbedded with calcareous, dark-reddish-brown (10 R 3/4) siltstone in upward-fining sequences in upper part of unit. Grades down into and intertongues with Reston Member of Manassas Sandstone (TRmr). Estimated thickness as much as 3,000 ft

TRmt Tuscarora Creek Member—Light (N7)- to dark-gray (N3) and light-red (5 R 6/6) conglomerate composed of very fine to very coarse grained, angular to subangular pebbles and cobbles of limestone and dolomite within matrix chiefly of limestone and dolomite granules and dusky-red (5 R 3/4) to grayish-red (5 R 4/2), clayey sand and silt with calcite cement. Limestone and dolomite clasts derived from Cambrian and Ordovician carbonate strata. Estimated thickness ranges from 0 to 233 ft

TRmr Reston Member—Light-gray (N7) to pinkish-gray (5 YR 8/1) variegated pebble, cobble, and boulder conglomerate containing clasts of phyllite, schist, quartzite, and quartz in poorly sorted, coarse-grained, arkosic sandstone matrix; locally interbedded with pale-reddish-brown (10 R 5/4) sandstone and siltstone. Basal conglomerate unconformably overlies metasedimentary rocks of Westminster terrane. Estimated thickness as much as 70 ft

METASEDIMENTARY ROCKS OF THE FREDERICK VALLEY SYNCLINORIUM

Grove Formation (Lower Ordovician and Upper Cambrian)

Ogu Upper member (Lower Ordovician)—Medium-light-gray (N6), locally sandy, thrombolitic and stromatolitic algal limestone thickly interbedded with medium-gray (N5), laminated dolomitic limestone and olive-gray (5 YR 4/1) dolomite. Thickness is greater than 450 ft

O€gl Lower member (Lower Ordovician and Upper Cambrian)—Medium-light-gray (N6) to medium-gray (N5), thickly bedded and crossbedded, arenaceous limestone and sandy dolomitic limestone containing 1-ft-thick interbeds of medium-light-gray (N6) sandy dolomite. Thickness is approximately 150 to 400 ft

Frederick Formation (Upper Cambrian)

€fl Lime Kiln Member—Interbedded, thinly laminated to thinly bedded, dark-gray (N3), fine-grained limestone; calcareous shale; and fine-grained, medium-bedded limestone near base. Becomes more thickly interbedded toward the top with medium-dark-gray (N4), fine-grained, wavy-bedded limestone containing local stromatolitic algal beds. Near top, member becomes interbedded with medium-light-gray (N6), crossbedded, sandy limestone. Thickness is 600 ft

€fa Adamstown Member—Medium-dark-gray (N4) to dark-gray (N3), fine-grained, argillaceous limestone thinly interbedded with dusky-yellow (5 Y 6/4) to medium-dark-gray (N4), silty dolomite. Limestone beds range from .01 to 1.55 in. in thickness. Includes several thin, dark-greenish-gray (5 G 4/1) to greenish-black (5 G 2/1), light-olive-brown (5 Y 5/6) weathering, silty, calcareous shale intervals 6 to 16 ft thick throughout member. Top of member is mapped at base of the lowest medium to thick bed of sandy or algal limestone. Thickness is approximately 1,600 ft

€fr **€frs** Rocky Springs Station Member—Dark-gray (N3), nodular to lumpy-bedded, argillaceous, dolomitic limestone at base containing an interval of grayish-black (N2), platy shale (€frs) 45 to 60 ft thick mapped along the eastern flank of the Frederick Valley synclinorium. Upsection grades into dark-gray (N3), laminated to flaggy-bedded limestone containing dusky-yellow (5 Y 6/4) to light-olive-gray (5 Y 6/1), silty dolomitic partings and laminations and contains 1- to 32-ft-thick intervals of medium-dark-gray (N4), polymictic breccia that grade upsection into medium-gray (N5), planar-bedded, arenaceous limestone. Clast sizes in breccia range from sand size to 1 ft diameter on western flank of Frederick Valley synclinorium and diminish to less than 1.2 to 2 in. in diameter on eastern flank of Frederick Valley synclinorium. Top of member is mapped at top of stratigraphically highest polymictic breccia or sandstone interval. Thickness ranges from approximately 1,200 to 2,500 ft

€ar **Araby Formation (Middle and Lower Cambrian)**—Light-olive-gray (5 Y 5/2), pale-brown (5 YR 5/2), and moderate-brown (5 YR 4/4), mottled metasiltstone containing sandy intervals. Pervasively cleaved bedding typically obscure

METASEDIMENTARY ROCKS OF THE BLUE RIDGE-SOUTH MOUNTAIN ANTICLINORIUM

€t **Tomstown Formation (Lower Cambrian)**—Medium-light-gray (N6) to medium-gray (N5), saccharoidal dolomite containing thin (0.04 in.) layers of sericite. Found in northwest corner of quadrangle where completely covered by colluvium (Qc). Thickness of 150 ft measured in drill core by Hoy and Schumacher (1956)

€a **Antietam Formation of Chilhowee Group (Lower Cambrian)**—Light-olive-gray (5 Y 6/1) to olive-gray (5 Y 4/1), medium- to coarse-grained, medium-bedded, locally ferruginous, micaceous, silty metasandstone interbedded with very fine grained, silty metasandstone to sandy metasiltstone. Poorly exposed. Thickness estimated at 300 ft

€h **Harpers Formation of Chilhowee Group (Lower Cambrian)**—Brownish-gray (5 YR 6/1) to dark-greenish-gray (5 G 4/1), silty, phyllitic metashale to highly sheared, phyllitic metasiltstone containing intervals of brownish-gray (5 YR 4/1), medium-grained, silty metasandstone. Poorly exposed. Thickness estimated at greater than 900 ft

LOWER CAMBRIAN(?) METASEDIMENTARY ROCKS OF THE SUGARLOAF MOUNTAIN ANTICLINORIUM

€u **€uq** **€ul** **Urbana Formation (Lower Cambrian?)**—Predominantly medium-olive-brown (5 Y 4/4) to light-olive-gray (5 Y 5/2), poorly sorted, graded, crossbedded, ripple-marked, calcareous metagraywacke and metasiltstone. Contains light-olive-gray (5 Y 6/1), and light-brownish-gray (5 YR 6/1), fine- to coarse-grained, thin- to medium-bedded, crossbedded, pitted, friable, lensoidal, discontinuous very calcareous metasandstone and quartzite (€uq). Interbedded with light-brown (5 YR 5/6) laminated metasiltstone. Also contains light-gray (N7) to greenish-gray (5 G 6/1), thin-bedded crystalline marble (€ul) in laminated beds of indeterminate thickness marked by seams of sericite and chlorite. Poorly exposed; produces distinctive reddish-orange (10 R 6/6) soils

€su **€sm** **€sl** **Sugarloaf Mountain Quartzite (Lower Cambrian?)**—Pinkish-gray (5 YR 8/1) to white (N9), fine- to medium-grained, medium-bedded to massive, well-sorted, graded, crossbedded, ripple-marked, granular quartzite. Quartzite interbedded with seldomly exposed medium-brown (5 YR 4/4), quartzose metasiltstone and dusky-blue (5 PB 3/2), laminated metasiltstone (similar to that of the conformably overlying Urbana Formation) underlies topographic swales. Lower (€sl), middle (€sm), and upper (€su) members (informal) separately mapped based on topographic expression of ridge-forming basal units because quartzites are virtually identical. Total thickness is approximately 2,000 ft

METASEDIMENTARY ROCKS OF THE WESTMINSTER TERRANE

€Zi **Ijamsville Phyllite (Lower Cambrian? and Late Proterozoic?)**—Dusky-blue (5 PB 3/2), grayish-blue (PB 5/2), very dusky reddish-purple (5 RP 2/2), and greenish-gray (5 G 6/1) to pale-olive (10 Y 6/2) phyllite, phyllonite, and minor slate. Contains abundant vein quartz. Intensely folded and sheared. Finely laminated beds seen only in slate. Phyllite consists mostly of muscovite and chlorite and local paragonite and chloritoid. Lustrous sheen results from paragonite (determined by X-ray diffraction) and dark color results from abundant hematite dust

€Zs **Silver Run Limestone (Lower Cambrian? and Late Proterozoic?)**—Light-bluish-gray (5 B 7/1), and medium-light-gray (N6), thin-bedded, laminated, carbonaceous and argillaceous metalimestone and minor medium-dark-gray (N4), finely laminated carbonaceous phyllite. Complexly folded and exposed only along a tributary of Monocacy River west of St. Paul Church

EXPLANATION OF MAP SYMBOLS

Contact—Dashed where approximately located or projected in cross section; dotted where concealed

Faults—Dashed where approximately located or projected in cross section; dotted where concealed

- Thrust fault—Sawteeth on upper plate. In cross section, half arrow shows direction of relative movement
- Overturned thrust fault with recurrent thrust motion—Sawteeth on upper plate, open bar on early upper plate
- Normal fault—Bar and ball on downthrown block

Folds—Dotted where concealed

- Anticline—Showing axial trace and direction of plunge where known
- Overturned anticline—Showing axial trace surface and direction of dip of limbs and plunge where known
- Syncline—Showing axial trace and direction of plunge where known
- Overturned syncline—Showing axial trace and direction of dip of limbs and plunge where known
- Arch in transposition foliation (F)—Found in Ijamsville Phyllite in northeastern part of quadrangle
- Trough in transposition foliation (F)—Found in Ijamsville Phyllite in northeastern part of quadrangle
- 11 Minor anticline—Showing bearing and plunge of axis
- 9 Minor syncline—Showing bearing and plunge of axis
- 25 Minor asymmetric antiform (F_2) in complex fold train—Showing bearing and plunge of axis

PLANAR FEATURES

(May be combined with each other or with linear features)

Strike and dip of beds—Ball indicates top of bed known from sedimentary structures

- Inclined
- Vertical
- Horizontal
- 17 Overturned

Strike and dip of slaty cleavage

- 67 Inclined
- Vertical

Strike and dip of crenulation cleavage

- 57 Inclined
- Vertical

Strike and dip of transposition foliation

- 70 Inclined
- Vertical

Strike and dip of joint

- 66 Inclined
- Vertical

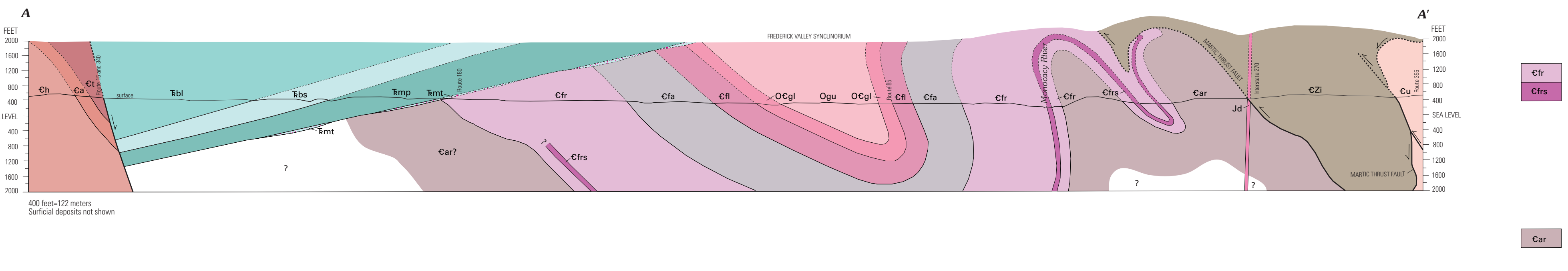
LINEAR FEATURES

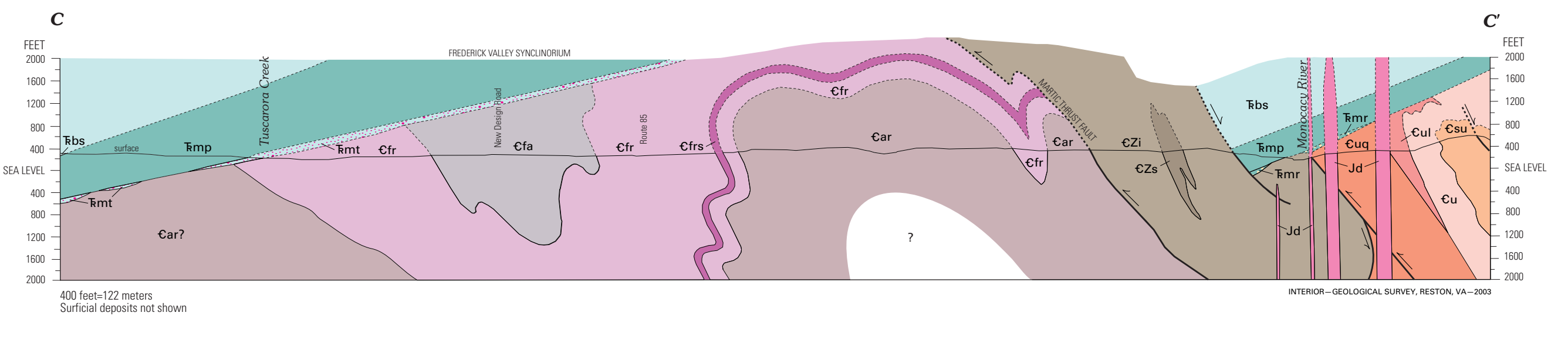
(May be combined with planar features)

- 80 **Bearing and plunge of mineral lineation**
- 17 **Bearing and plunge of intersection of bedding and slaty cleavage**

OTHER FEATURES

- sl **Quarry**—sl, slate
- 1 **Locality of geochemical sample in table 1**
- **Sinkhole**
- **Metasiltstone interbed in Sugarloaf Mountain Quartzite**
- **Bedrock landslide**—Hachures on escarpment





DISCUSSION

INTRODUCTION AND GEOLOGIC SETTING

The Buckeystown quadrangle is underlain mostly by rocks of the western Piedmont province and a portion of the eastern Blue Ridge province. The western Piedmont province is underlain by Late Proterozoic(?) and Lower Cambrian(?) metasedimentary rocks of the Westminster terrane, Lower and Middle Cambrian metasedimentary rocks and Upper Cambrian to Lower Ordovician carbonate rocks of the Frederick Valley synclinorium, Upper Triassic sedimentary rocks of the Mesozoic Culpeper basin, and Early Jurassic dikes; Lower Cambrian metasedimentary rocks underlie the Blue Ridge province. Within the western Piedmont, Lower Cambrian(?) metasedimentary rocks of the Sugarloaf Mountain anticlinorium are interpreted to be exposed in a tectonic window (A.A. Drake, Jr., U.S. Geological Survey, oral commun., 1989; Horton and others, 1989; Rankin and others, 1989) through the complexly deformed allochthonous rocks of the Westminster terrane (Muller and others, 1989). The undated rocks of the Westminster terrane are interpreted to be rise-slope deep-water deposits of the Iapetus Ocean that were transported westward onto the Laurentian margin (ancestral North America) along the Martic thrust fault during the Ordovician Taconic orogeny (Horton and others, 1989). Continental margin strata, which underlie the Sugarloaf Mountain anticlinorium and continental margin-slope strata which underlie the Frederick Valley synclinorium, are here correlated with the Lower Cambrian Chilhowee Group and overlying carbonate rocks on the limbs of the Blue Ridge-South Mountain anticlinorium to the west. The relation of the Sugarloaf Mountain Quartzite (fig. 1) (Jonas and Stose, 1938b) to surrounding rocks is controversial (Scotford, 1951; Stose and Stose, 1951; Thomas, 1952). The Martic thrust fault (fig. 1) (Jonas, 1924, 1927; Knopf and Jonas, 1929) and the interpretation that the Sugarloaf Mountain anticlinorium (Scotford, 1951; Thomas, 1952) is a tectonic window through the Martic thrust sheet (A.A. Drake, Jr., U.S. Geological Survey, oral commun., 1989) further complicates the stratigraphic correlation of these rocks. Upper Triassic sedimentary rocks of the Culpeper basin consist of westward-dipping conglomerate, sandstone, and siltstone. These rocks, as well as intrusive Early Jurassic diabase dikes, accumulated during an early Mesozoic rifting event that resulted in the opening of the Atlantic Ocean. Contractional faults of Paleozoic orogenesis and extensional faults related to Mesozoic rifting indicate a complex tectonic history for this region.

Cenozoic deposits, which overlie the bedrock, include high- and low-level alluvial terraces, residual gravel, colluvium, and alluvium. Terrace deposits of the ancestral Potomac River and the Monocacy River are as much as 183 ft and 140 ft, respectively, above the present river levels. Isolated residual gravel deposits that form in place from the weathering of the Upper Cambrian Frederick Formation superficially resemble terrace deposits. Colluvium of quartzite boulders is concentrated in hillslope depressions on Sugarloaf Mountain, and fanlike aprons of colluvial quartz pebbles cover the Triassic rocks on the west side of the Culpeper basin. Alluvium was mapped along the Potomac and Monocacy Rivers and all their tributaries. Altitude ranges from 200 ft along the Potomac River to 1,282 ft on the crest of Sugarloaf Mountain. The map area includes the Chesapeake and Ohio Canal National Historical Park, and the Monocacy Natural Resources Area. Sugarloaf Mountain is a registered natural landmark.

Parts of the Buckeystown quadrangle were mapped by Jonas and Stose (1938a, scale 1:62,500), Scotford (1951, scale 1:12,500), Thomas (1952, scale 1:25,000), Cloos and Cook (1953, 1:62,500), Reinhardt (1974, scale 1:62,500), Froelich (1975, scale 1:62,500), and Lee (1979, scale 1:24,000).

The map area is subdivided into five domains (fig. 1). Allochthonous rocks of the Westminster terrane are thrust onto rocks of the Frederick Valley synclinorium. Within the Westminster terrane of Muller and others (1989), the Sugarloaf Mountain Quartzite and Urbana Formation underlie the parautochthonous Sugarloaf Mountain anticlinorium. The Lower and Middle Cambrian Araby Formation and Upper Cambrian Frederick Formation crop out on the east limb of the Frederick Valley synclinorium. The Frederick Formation and Upper Cambrian and Lower Ordovician Grove Formation lie in the trough of the Frederick Valley synclinorium. Lower Cambrian Harpers, Antietam, and Tomstown Formations crop out on the east limb of the Blue Ridge-South Mountain anticlinorium in the extreme northwest corner of the map. The Blue Ridge-South Mountain anticlinorium is separated from the Frederick Valley synclinorium by Upper Triassic sedimentary rocks in the Culpeper basin half graben. Figure 1 shows the type localities of rock units.

ROCKS OF THE WESTMINSTER TERRANE

Silver Run Limestone

The Silver Run Limestone (€Zs) (Jonas and Stose, 1938b) was named for a karstic valley in the Littlestown quadrangle, Carroll County, Md., but the best exposure is considered to be in the Union Bridge quadrangle (Edwards, 1986), Frederick County, Md. In the Buckeystown quadrangle, thin-bedded, laminated, argillaceous metalimestone crops out along a tributary north of the Monocacy River northwest of St. Paul Church. By inference, the metalimestone underlies the linear valley along strike as it is well exposed along the Monocacy River to the south in the Poolesville quadrangle (Southworth, 1998). There, the metalimestone is overlain by Ijamsville Phyllite. In the Buckeystown quadrangle the metalimestone crops out within polydeformed phyllite of the Ijamsville Phyllite. Fisher (1978) mapped the Silver Run Limestone within Ijamsville Phyllite in the New Windsor quadrangle and also interpreted the metalimestone to be beneath the phyllite. The Silver Run Limestone probably was deposited in deep water prior to the mud (protolith of the phyllite). Alternatively, the metalimestone may constitute blocks (sedimentary olistoliths) deposited in the mud.

Ijamsville Phyllite

The type locality of the blue, green, and purple phyllitic slate of the Ijamsville Phyllite (Jonas and Stose, 1938b) is the town of Ijamsville in the Urbana quadrangle (Southworth, 1999). Rocks composing the Ijamsville Phyllite are (in order of decreasing abundance) hematite-rich muscovite-chlorite-paragonite-chloritoid phyllite, phyllonite, and slate (undifferentiated) (€Zi). The Ijamsville Phyllite is characterized by composite foliations, abundant and strongly folded vein quartz, and polymetamorphic features. The unit is commonly poorly exposed, but its presence is indicated by phyllite chips and an abundant float of vein quartz that mantles the clay-rich soil of a dissected plateau. The Ijamsville Phyllite is located in a fault zone, the base of which is the Martic thrust fault.

Most of the Ijamsville in the Buckeystown quadrangle is phyllonite that contains abundant vein quartz. These rocks are best exposed along Bennett Creek west of Park Mills and along Maryland Route 355 in the northeast part of the map. Slate is well exposed in a quarry west of Hope Hill.

The hematite-rich phyllite originally was deep-water mud deposited on the continental slope (fig. 1). Chemical data (table 1 and fig. 2) of the phyllites shows that the ratio of K_2O to total alkalies differs and may reflect different source areas for the parental muds (Fisher, 1978) or may indicate a volcanic component of the muds (Clark, 1924).

LOWER CAMBRIAN(?) ROCKS OF THE SUGARLOAF MOUNTAIN ANTICLINORIUM

Sugarloaf Mountain Quartzite

The Sugarloaf Mountain Quartzite (Jonas and Stose, 1938b) was named for Sugarloaf Mountain. The Sugarloaf Mountain Quartzite consists of medium-bedded to massive, medium- to coarse-grained, saccharoidal, white, gray, tan, and maroon quartzite cemented by silica and sericite. Crossbedding and sparse ripple marks support the interpretation that these rocks are continental-margin deposits. The quartzite contains detrital sphene, tourmaline, zircon, and ilmenite, and characteristic clots of hematite after magnetite(?). Dark-blue to black, laminated metasiltstone and phyllite are interbedded with the quartzite. Erosion of the rocks forms recessive topographic swales. The laminated metasiltstone is lithologically similar to metasiltstone of the Urbana Formation that conformably overlies the highest quartzite.

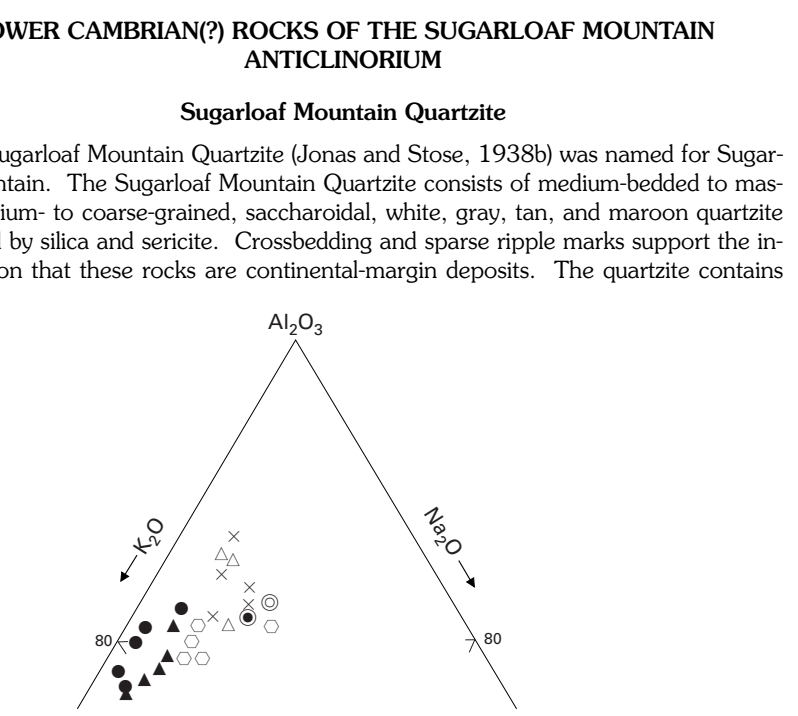


Figure 2.—Portion of an Al_2O_3-K_2O-Na_2O plot for phyllites in the Westminster terrane of Maryland (Fisher, 1978; A.A. Drake, Jr., U.S. Geological Survey, unpub. data, 1994) and phyllite on the southeastern limb of the Blue Ridge anticlinorium in central Virginia (Evans and Milici, 1994).

The Sugarloaf Mountain Quartzite is divided into informal lower (€sl), middle (€sm), and upper (€su) members that were mapped according to their ridge- and ledge-forming habit; otherwise, the rocks are virtually indistinguishable. Stereoscopic aerial photographs and an orthophotoquadrangle map were used to support field mapping of the quartzite units. The lower member (€sl) is poorly exposed in the core of the Sugarloaf Mountain anticlinorium. The rocks are well exposed along the Northern Peaks trail northwest of the Mountain Loop trail. Crossbedded quartzite can be seen immediately east of Furnace Branch Road north of Bells Chapel. The base of the lower member is not exposed; therefore, the 600 ft thickness is approximate. The middle member (€sm) forms a prominent ridge that is followed by the Northern Peaks trail north of the summit where the quartzite is approximately 800 ft thick. Quartzite of the middle member defines the anticline-syncline-anticline triplet of folds on the northern nose of the anticlinorium. These rocks are well exposed beneath the road and trail north of the west view parking lot. Ripple-marked quartzite can be seen south of the stone building at the west view. The upper member (€su) of the Sugarloaf Mountain Quartzite is best seen at the summit of Sugarloaf Mountain where approximately 300 ft of quartzite has been folded into a series of anticlines and synclines. Gently folded rocks of the upper member can be seen west of Sugarloaf Road where they plunge beneath rocks of the Urbana Formation. The upper member can also be seen where Bear Branch breaches "west ridge," especially north of the water gap at "White Rocks" (quotation marks refer to local names of features shown on accompanying trail map).

The Sugarloaf Mountain Quartzite is correlated with the Lower Cambrian Weverton Formation of the Chilhowee Group which crops out on the limbs of the Blue Ridge-South Mountain anticlinorium (fig. 1). The Sugarloaf Mountain Quartzite is about 1,800 ft thick.

Urbana Formation

The Urbana Formation (€u) (Edwards, 1986; Urbana Phyllite of Jonas and Stose, 1938b) conformably overlies the Sugarloaf Mountain Quartzite (€su). The contact may be seen along a tributary to Bennett Creek at the north end of the Sugarloaf Mountain anticlinorium and on the west side of "west ridge" south of Bear Branch. The Urbana Formation contains a wide variety of metasedimentary rocks that include, in decreasing abundance, metasiltstone and metagraywacke (€u), calcareous metasandstone and quartzite (€uq), and marble (€ul). Locally, these rocks are poorly exposed because of a deep regolith of the decomposed calcareous and sandy strata.

The metasiltstone and metagraywacke (€u) are poorly sorted sediments that contain detrital saussurite, calcite, orthoclase, tourmaline, and olivine(?). Bedding is defined by concentrations of heavy minerals. These rocks are best seen north of Bennett Creek. The calcareous metasandstone and quartzite unit (€uq) of the Urbana Formation is lensoid, discontinuous, and difficult to trace in the field. The calcareous metasandstone is medium- to coarse-grained quartz sand in a clay-rich matrix containing abundant crystals and seams of calcite. The rock is characteristically friable and contains many vugs. The quartzite consists of medium- to coarse-grained quartz and polycrystalline quartz lithic clasts cemented by silica; accessory detrital minerals include zircon, magnetite, orthoclase, perthite, plagioclase, and ilmenite. The quartzite is best seen along Bennett Creek south of Park Mills. Quartzite containing blue-black quartzite clasts can be seen along the Frederick and Montgomery County line east of Stronghold. Marble (€ul) contains sericite, chlorite, graphite, and detrital quartz, zircon, microcline, plagioclase, and orthoclase. The marble is well exposed on the bluffs of Bennett Creek east of Bear Branch. This impure carbonate rock does not resemble any other carbonate rock within the quadrangle.

Rocks of the Urbana Formation are correlated with lithologically similar metasiltstone, metasandstone, and limy metashale of the Lower Cambrian Harpers Formation of the Chilhowee Group in the Blue Ridge-South Mountain anticlinorium, as earlier proposed by Scotford (1951). Rocks of the Urbana Formation are crossbedded and ripple-marked as first recognized by Hopson (1964) and are interpreted to be continental margin deposits.

CAMBRIAN AND ORDOVICIAN ROCKS OF THE FREDERICK VALLEY SYNCLINORIUM

Araby Formation

The Lower and Middle Cambrian Araby Formation (€ar) (Reinhardt, 1974, 1977) consists predominantly of argillaceous, burrowed, mottled metasiltstone that contains sandy intervals and has a phyllitic metashale at the top. The type locality is along Bush Creek south of Frederick Junction. Rocks of the Araby Formation are well exposed along the railroad tracks east of Frederick Junction, along the Monocacy River east of Buckeystown, west of Greenfield Mills, and along the road west of Lilypons. The metasiltstone is highly cleaved and jointed and the bedding is commonly obscure. The rocks underlie ridges that have a thin soil. Classic ridge and valley topography formed on the east limb of the Frederick Valley synclinorium where the Araby is tightly folded with the Frederick Formation.

The metasiltstone consists predominantly of quartz sand grains, polycrystalline quartz, and opaque minerals that are supported by a clay-rich matrix containing abundant hematite. Sericite, chlorite, magnetite octahedra, sphene, zircon, microcline, sanidine, and plagioclase are accessory grains. The Araby Formation probably represents the deep-water slope facies of a starved clastic basin that persisted in the Cambrian (Reinhardt, 1977). Rocks of the Araby Formation contain fragments of the trilobite *Olenellus* of late Early Cambrian age (Reinhardt, 1974). The Araby Formation is conformably overlain by carbonate rocks of the Rocky Springs Station Member of the Frederick Formation (€fr). The contact can be seen in a tributary south of Greenfield Mills.

Frederick Formation

The Upper Cambrian Frederick Formation (Frederick Limestone of Keyes, 1890; Stose and Stose, 1946; Reinhardt, 1974, 1977) is a thick interval of thin- to medium-bedded limestone, dolomite, and thin intervals of shale and sandstone. Because of the numerous rock types present in this unit, it is here revised as the Frederick Formation. The three members of Reinhardt (1974 and 1977) were recognized and mapped within the Frederick Formation.

Rocky Springs Station Member

The lower member of the Frederick Formation, the Rocky Springs Station Member (€fr) (Reinhardt, 1974), is characterized by intervals of locally traceable polymictic breccia. This member resulted from off-shelf deposition at the toe of a slope (Reinhardt, 1974). The Rocky Springs Station is best exposed along the Monocacy River within the Monocacy National Battlefield, southwest of Maryland Route 355. Good outcrops can also be seen along Bennett Creek, north of Lilypons. An interval of gray to black shale (€frs) occurs on the east limb of the Frederick Valley synclinorium and can be seen along Maryland Route 355. The trilobite *Olenellus* was found near the top of the member in thin-bedded limestone (Reinhardt, 1974).

Adamstown Member

The Adamstown Member (€fa) (Reinhardt, 1974), the middle member of the Frederick Formation, consists of thinly bedded limestone and thin intervals of shale. The Adamstown resulted from deposition in a basinal environment (Reinhardt, 1974). The Adamstown is well exposed on the south and north faces of the Essroc quarry at Lime Kiln. The trilobite *Olenellus*, brachiopods, and echinoderms are found as fossil hash southeast of Doubs (Reinhardt, 1974).

Lime Kiln Member

The Lime Kiln Member (€fl) (Reinhardt, 1974), the uppermost member of the Frederick Formation, consists of interbedded, thinly bedded limestone and algal limestone. The member records the aggradation from basinal deposition to shallow shelf deposition (Reinhardt, 1974). The Lime Kiln is best exposed along the quarry roads within the Essroc quarry at Lime Kiln. The trilobite *Olenellus*, brachiopods, and echinoderms are found near Buckeystown Station and cephalopods are found west of Lime Kiln as fossil debris (Reinhardt, 1974).

Grove Formation

The Grove Formation (Stose and Jonas, 1935; Jonas and Stose, 1938b; Reinhardt, 1974) is an interval of Upper Cambrian and Lower Ordovician carbonate rock in the core of the Frederick Valley synclinorium. Two informal members were mapped within the formation in the Buckeystown quadrangle. Rocks of the Grove Formation contain trilobites, brachiopods, cephalopods, and conodonts of Late Cambrian and early Early Ordovician age (Reinhardt, 1974, 1977).

Lower member

The basal strata of the Grove Formation consist of crossbedded calcareous sandstone here informally called the lower member (O€gl). Because of its marked compositional difference from underlying and overlying strata, this member makes an excellent marker for mapping purposes. The lower member is well exposed within the abandoned quarry east of the main Essroc quarry at Lime Kiln.

Upper member

Above the basal sandstone of the Grove Formation are medium- to thick-bedded limestone and dolomite of the informal upper member (Ogu). The strata are arranged in cycles consisting of thrombolitic and stromatolitic limestone and laminated dolomite. This member is well exposed in pastures north of Adamstown Road and west of Maryland Route 85 and within several abandoned quarries near the large lime kilns along the railroad tracks east of the Essroc quarry.

LOWER CAMBRIAN METASEDIMENTARY ROCKS OF THE BLUE RIDGE-SOUTH MOUNTAIN ANTICLINORIUM

Harpers Formation

The Lower Cambrian Harpers Formation (€h) (Keith, 1894) of the Chilhowee Group consists of phyllitic metashale, metasiltstone, and silty metasandstone. The Harpers is poorly exposed in the extreme northwest corner of the map area. The type locality is approximately 13 mi to the west at Harpers Ferry, W. Va. On the west limb of the Blue Ridge-South Mountain anticlinorium, rocks of the Harpers Formation contain *Skolithos* burrows and *Rusophycus* traces (Nickelsen, 1956; Brezinski, 1992).

Antietam Formation

The Lower Cambrian Antietam Formation (€a) (Keith, 1894) of the Chilhowee Group consists of metasandstone and sandy metasiltstone that underlies the main ridge of the Blue Ridge-South Mountain anticlinorium in the extreme northwest corner of the map area. The type locality of the Antietam Formation is approximately 13 mi to the west at Antietam, Md. The Antietam Formation is the lithic equivalent of the Araby Formation although the Antietam Formation is older. On the west limb of the Blue Ridge-South Mountain anticlinorium, the Antietam contains the trilobite *Olenellus* (Walcott, 1896) and the trace fossils *Skolithos*, *Rusophycus*, and *Planolites* (Brezinski, 1992).

Tomstown Formation

Dolomite of the Lower Cambrian Tomstown Formation (€t) (Stose, 1906) was encountered in drill core along the Mesozoic basin border fault in the adjacent Point of Rocks quadrangle by Hoy and Schumacher (1956). The Antietam and Tomstown Formations are roughly time correlative to the Araby Formation exposed to the east. The type locality of the Tomstown Formation is approximately 30 mi to the northwest in Pennsylvania. The trilobite *Olenellus* (Fauth, 1968) and the mollusc *Salterella conulata* (Brezinski, 1992) have been recognized in the Tomstown Formation on the west limb of the Blue Ridge-South Mountain anticlinorium.

MESOZOIC ROCKS

Culpeper Group of the Newark Supergroup

Manassas Sandstone

The Manassas Sandstone of Late Triassic age was divided into three members by Lee and Froelich (1989). The Reston and Tuscarora Creek Members are basal conglomerates that are overlain conformably by sandstone of the Poolesville Member.

Reston Member—The Reston Member of the Manassas Sandstone (TRmr) (Lee, 1977) is a basal conglomerate that unconformably overlies rocks of the Piedmont. The type locality is along the Washington and Old Dominion bike trail near Reston Parkway in the Vienna 7.5-minute quadrangle in northern Virginia (Drake and Lee, 1989). The Reston Member is characterized by cobbles and pebbles of vein quartz and subangular phyllite and schist derived from the underlying Ijamsville Phyllite in the map area. Good outcrops can be seen north of Monocacy River, east of St. Paul Church.

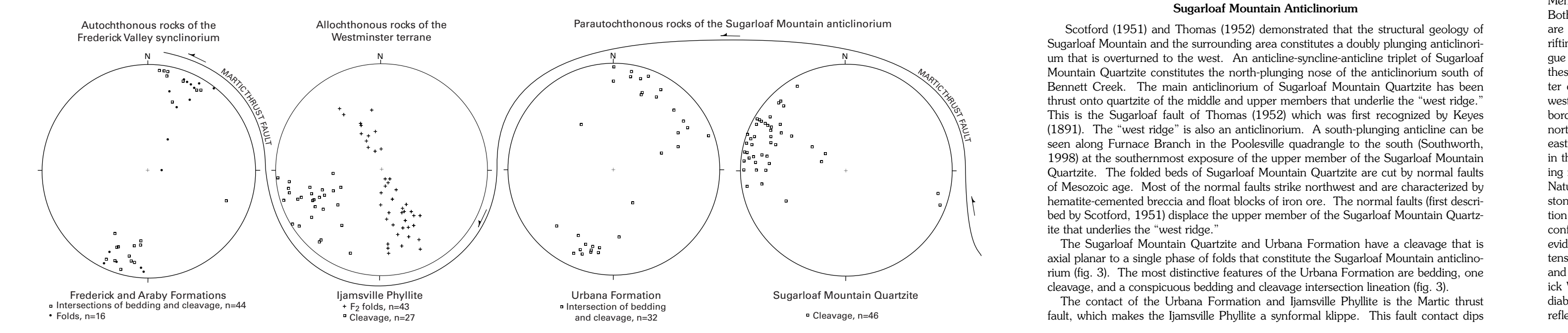
Tuscarora Creek Member—The Tuscarora Creek Member (TRmt) (Lee and Froelich, 1989) is a basal conglomerate that unconformably overlies carbonate rocks of the Upper Cambrian Frederick Formation. It is laterally equivalent to the Reston Member but differs lithically because of different source rocks. The unit can be best seen at the type locality along Route 28, east of Tuscarora Creek and west of Tuscarora. The Tuscarora Creek Member is characterized by the presence of limestone and dolomite clasts derived from the underlying Frederick Formation. The conglomerate is locally lensoidal and discontinuous and was interpreted to be a channel fill and (or) fan deposits (Lee and Froelich, 1989).

Poolesville Member—The Poolesville Member (TRmp) (Lee and Froelich, 1989) is an arkosic, muscovite-rich sandstone that contains sparse quartz pebbles and fines upward to siltstone. The unit is transitional with the basal conglomerate members. The Poolesville Member grades up into the Balls Bluff Siltstone; therefore, the contact in this quadrangle is approximate. The type locality is 7 mi to the south at Poolesville, Md. In this quadrangle, the unit is best exposed between Pleasant View and Doubs along Route 28 west of Tuscarora Creek.

Balls Bluff Siltstone

The type locality of the Balls Bluff Siltstone (Lee and Froelich, 1989) is the Balls Bluff National Cemetery in the adjacent Waterford quadrangle, Va. (Burton and others, 1995). Although the unit is predominantly siltstone (TRbs), it locally contains interbedded sandstone. In the map area, the Balls Bluff Siltstone is poorly exposed but can be seen west of Doubs.

Leesburg Member—The Leesburg Member (TRbl) of the Balls Bluff Siltstone (Lee and Froelich, 1989) is a conspicuous carbonate-clast fanglomerate composed of subangular to subrounded boulders, cobbles, and pebbles of limestone and dolomite in a reddish-brown sandy siltstone matrix. Lindholm and others (1979) suggested that the carbonate clasts were derived from Cambrian and Ordovician rocks of the Grove, Elbrook, and Conococheague Formations. Isolated outcrops are exposed along the road northwest of Adamstown. The conglomerate was interpreted by Smoot (1989) to be debris flows on an alluvial fan. The conglomerate, locally called "Potomac marble," was used for the columns in Statuary Hall of the Capitol building in Washington, D.C.


Autochthonous rocks of the Frederick Valley synclinorium

Allochthonous rocks of the Westminster terrane

Parautochthonous rocks of the Sugarloaf Mountain anticlinorium

Frederick and Araby Formations
- Intersections of bedding and cleavage, n=44
- Folds, n=16

Ijamsville Phyllite
- F_2 folds, n=43
- Cleavage, n=27

Urbana Formation
- Intersection of bedding and cleavage, n=32

Sugarloaf Mountain Quartzite
- Cleavage, n=46

Figure 3.—Lower hemisphere equal-area projections of structural data of rocks of the Buckeystown, Md., quadrangle, by structural domains.

Thermally Metamorphosed Rocks

Siltstone, shale, and minor sandstone were baked by metamorphism to hornfels (TRtm) adjacent to the diabase dike at the southern edge of the map. These brittle rocks are poorly exposed along the bluff of the Monocacy River. Metasiltstone of the Urbana Formation was locally baked to hornfels by contact metamorphism

Diabase Dikes

Near vertical, en echelon, north-, northeast-, and northwest-trending diabase dikes (Jd) were emplaced at about 200 Ma based on $^{40}Ar/^{39}Ar$ data (Kunk and others, 1992) during continental rifting that led to the opening of the Atlantic Ocean. The diabase is dense, hard, and weathers to large spheroidal boulders aligned along ridges. The diabase dike swarm that transects the eastern part of this quadrangle has been traced over 106 mi from Fauquier Co., Va., to Emittsburg, Md. (J.P. Smoot and others, U.S. Geological Survey, unpub. data, 1994).

CENOZOIC SURFICIAL DEPOSITS

High-level terrace deposits (QTt) of the ancestral Potomac River are preserved 183 ft above the Potomac River north of Maryland Route 28 near Tuscarora. Cobbles of rounded quartzite have armoured the underlying limestone of the Frederick Formation. The original deposit may have been preserved in a sinkhole. Later preferential erosion formed a hillock by topographic inversion. In the Poolesville quadrangle to the south, similar deposits are as much as 288 ft above the Potomac River (Southworth, 1998). High-level terrace deposits of the ancestral Monocacy River are preserved 140 ft above the Monocacy River at the Monocacy National Battlefield and west of Monocacy Natural Resources Area. These terraces are undated but may be as old as 5 Ma and as young as 1 Ma.

Low-level terrace deposits (Qt) of the Potomac and Monocacy Rivers and Tuscarora Creek are as much as 80 ft above the present channels. Terraces of the Monocacy River are well preserved east of Buckeystown adjacent to broad meanders.

Residuum (Qr) superficially resembles the terrace deposits but instead is characterized by pebble- to boulder-size, angular to euhedral, white quartz. The residuum resulted from in-place weathering of the underlying carbonate rocks. The original quartz filled veins and cavities in the limestone. Some of the cobbles are geodes containing quartz crystals.

Colluvium (Qc) is found on Sugarloaf Mountain and along the western margin of the Culpeper basin in the northwest part of the map area. Coarse colluvium derived from quartzite is concentrated in hillslope depressions on Sugarloaf Mountain. Large colluvial blocks that spalled from the face of the summit can be seen at the parking lot and trails at the "west view." Colluvial deposits 10 ft thick choke Bear Branch and can be seen at the water gap of "west ridge." Fine colluvium derived from weathering of the rocks of the Blue Ridge-South Mountain anticlinorium forms dissected aprons that mantle the Paleozoic and Mesozoic bedrock. This colluvium consists predominantly of subangular to subrounded pebbles and cobbles of vein quartz and minor quartzite and metasandstone. Locally, the finer colluvium resembles both terrace deposits and the residuum unit.

Alluvium (Qal) lies along all drainages, but the best deposits are along the Potomac and Monocacy Rivers. The current river channels are incised into bedrock and the alluvium crops out on the banks.

STRUCTURAL GEOLOGY

In the Buckeystown quadrangle, polydeformed slope rise to slope prism deposits were thrust over parautochthonous rocks of the Sugarloaf Mountain anticlinorium and Frederick Valley synclinorium along the Martic thrust fault during the Ordovician Taconic orogeny (A.A. Drake, Jr., U.S. Geological Survey, oral commun., 1989; Drake and others, 1989; Horton and others, 1989; Rankin and others, 1989; Rankin and others, 1990). In this interpretation, the Martic thrust sheet was folded with rocks of the Sugarloaf Mountain anticlinorium during the late Paleozoic Alleghanian orogeny; subsequent erosion exposed the Sugarloaf Mountain Quartzite and Urbana Formation in a tectonic window (fig. 1). Like the Blue Ridge-South Mountain anticlinorium, rocks of the Sugarloaf Mountain anticlinorium and Frederick Valley synclinorium are mostly continental-margin deposits of Laurentia and they contain evidence of only one phase of folding and axial-planar cleavage development (fig. 2). The overlying polydeformed Silver Run Limestone and Ijamsville Phyllite of the Westminster terrane are allochthonous. Contractional motion of the Martic thrust fault occurred during the Ordovician with later thrusting and possible dextral strike-slip motion occurring during the late Paleozoic Alleghanian orogeny. Because the geology is complex and the interpretations controversial, an interpretative sequence of cross sections (fig. 2) portrays this model.

Structural elements in the rocks include bedding, cleavage, transposition foliation, crenulation cleavage, mineral lineations, intersection lineations, folds, and faults. These elements are discussed below by terrane and geographic location. In summary, bedding, cleavage, and bedding-cleavage intersection of the rocks of the Sugarloaf Mountain anticlinorium and Frederick Valley synclinorium support the concept of one phase of folding. Cleavage in these parautochthonous rocks is mostly coplanar with transposition foliation in the allochthonous rocks. Second-phase folds of foliations and vein quartz in the allochthonous rocks of the Westminster terrane help to define the Martic thrust sheet.

Allochthonous Rocks of the Westminster Terrane

Polydeformed, allochthonous rocks of the Silver Run Limestone and Ijamsville Phyllite of the Westminster terrane constitute the Martic thrust sheet. The Martic thrust fault (Jonas, 1924; 1927; Knopf and Jonas, 1929; Southworth, 1996) has brought the Ijamsville Phyllite onto the Urbana, Araby, and Frederick Formations. The trace of the Martic thrust fault is straight from the Potomac River (Southworth, 1996) north to the Mesozoic Gettysburg basin (Edwards, 1988), suggesting a moderately steep attitude at the surface (fig. 1). Along Bennett Creek within one meter of the fault, transposition foliation in both the Ijamsville Phyllite (hanging wall) and Frederick Formation (footwall) dips 50° to the southeast. The Martic thrust fault was folded and erosion exposed rocks of the Sugarloaf Mountain anticlinorium in a tectonic window. On the west side of the window, the Martic was reactivated, bringing footwall rocks of the Urbana Formation onto the Ijamsville Phyllite during formation of the anticlinorium.

The dominant planar structure in the Ijamsville Phyllite is a composite foliation that consists mostly of a transposition foliation overprinted by a phyllonitic foliation and several sets of cleavage. Vein quartz was sheared and folded into steeply plunging isoclines. The transposition foliation and folded vein quartz were deformed by westward-verging inclined F_2 folds that plunge steeply to gently northwest or southeast (fig. 3). These folds have an axial-planar pressure-solution cleavage that strikes northwest and dips northeast and can be seen in the immediate hanging wall of the Martic thrust fault southeast of Lilypons and along Bennett Creek. Bedding is seen only as laminae in phyllite and slate in the quarry west of Hope Hill. In the Buckeystown quadrangle, rocks of the Ijamsville Phyllite constitute a fault zone. The Silver Run Limestone is poorly exposed in the map area. To the south in the Poolesville quadrangle (Southworth, 1998), the Silver Run Limestone is folded into F_2 antiforms that exhibit rodding and contain a strong south-plunging lineation.

Parautochthonous Rocks

Rocks of the Sugarloaf Mountain anticlinorium and Frederick Valley synclinorium have experienced a deformational and metamorphic history similar to that of the Blue Ridge-South Mountain anticlinorium to the west (Southworth and others, in press). In the Buckeystown quadrangle, these rocks are structurally and stratigraphically discordant to the allochthonous Silver Run Limestone and Ijamsville Phyllite. In general, the Sugarloaf Mountain anticlinorium and Frederick Valley synclinorium constitute a system of parasitic folds to the Blue Ridge-South Mountain anticlinorium (figs. 1 and 2).

Sugarloaf Mountain Anticlinorium

Scotford (1951) and Thomas (1952) demonstrated that the structural geology of Sugarloaf Mountain and the surrounding area constitutes a doubly plunging anticlinorium that is overturned to the west. An anticline-syncline-anticline triplet of Sugarloaf Mountain Quartzite constitutes the north-plunging nose of the anticlinorium south of Bennett Creek. The main anticlinorium of Sugarloaf Mountain Quartzite has been thrust onto quartzite of the middle and upper members that underlie the "west ridge." This is the Sugarloaf fault of Thomas (1952) which was first recognized by Keyes (1891). The "west ridge" is also an anticlinorium. A south-plunging anticline can be seen along Furnace Branch in the Poolesville quadrangle to the south (Southworth, 1998) at the southernmost exposure of the upper member of the Sugarloaf Mountain Quartzite. The folded beds of Sugarloaf Mountain Quartzite are cut by normal faults of Mesozoic age. Most of the normal faults strike northwest and are characterized by hematite-cemented breccia and float blocks of iron ore. The normal faults (first described by Scotford, 1951) displace the upper member of the Sugarloaf Mountain Quartzite that underlies the "west ridge."

The Sugarloaf Mountain Quartzite and Urbana Formation have a cleavage that is axial planar to a single phase of folds that constitute the Sugarloaf Mountain anticlinorium (fig. 3). The most distinctive features of the Urbana Formation are bedding, one cleavage, and a conspicuous bedding and cleavage intersection lineation (fig. 3).

The contact of the Urbana Formation and Ijamsville Phyllite is the Martic thrust fault, which makes the Ijamsville Phyllite a synformal klippe. This fault contact dips steeply eastward and quartzite of the Urbana Formation (€uq) is transected by the fault north of Flint Hill. The Urbana Formation was thrust onto the klippe of Ijamsville Phyllite during formation of the Sugarloaf Mountain anticlinorium. The klippe masks the relationship between the Urbana Formation and the Araby and Frederick Formations. A minor southwestward-directed intraformational thrust fault in the Urbana Formation south of Bennett Creek is related to the formation of the northeast-plunging anticlinorium.

Frederick Valley Synclinorium

The asymmetrical Frederick Valley synclinorium contains Cambrian and Ordovician rocks (Reinhardt, 1974). On the east limb of the synclinorium, rocks of the Araby and Frederick Formations were folded into a series of northeast- and southwest-plunging anticlines and synclines (fig. 3). These folds and attendant axial-plane cleavage are best seen north of Bennett Creek. The Araby Formation is well cleaved and highly jointed. South of Lilypons and northwest of Hope Hill, antiforms similar to those in the Araby Formation and topographic valleys suggest the presence of nonexposed folds of Frederick Formation. For example, the linear valley at Greenfield Mills is a tight syncline in the Frederick Formation.

The Lime Kiln Member of the Frederick Formation and the Grove Formation define a series of folds in the keel of the westward overturned synclinorium.

The Harpers, Antietam, and Tomstown (subsurface) Formations in the extreme northwest corner of the map area constitute a southeast-dipping homoclinal sequence that forms the east limb of the Blue Ridge-South Mountain anticlinorium and the west limb of the Frederick Valley synclinorium.

Culpeper Basin

The Culpeper basin in the Buckeystown quadrangle is a half-graben that is bounded on the west by an east-dipping normal fault that places the Upper Triassic Leesburg Member of the Balls Bluff Siltstone against dolomite of the Lower Cambrian Tomstown Formation (Whitaker, 1955). On the east side of the Culpeper basin, the Upper Triassic Tuscarora Creek Member of the Manassas Sandstone unconformably overlies the Upper Cambrian Frederick Formation and the Upper Triassic Reston Member of the Manassas Sandstone unconformably overlies the Ijamsville Phyllite. Both of the carbonate-clast fanglomerates (Tuscarora Creek and Leesburg Members) are debris-flow deposits that formed along fault escarpments during early Mesozoic rifting. Clasts of limestone and dolomite derived from the Elbrook and Conococheague Limestone, and the Grove Formation (Lindholm and others, 1979) suggest that these rocks formed a topographically high fault scarp that has since been eroded. After deposition and lithification of the fanglomerates, faulting continued, resulting in west-dipping strata. The greatest thickness of preserved basin fill is along the western border fault. Smaller down-faulted basins formed by the intersection of northeast and northwest-striking normal faults. The Triassic rocks between Tuscarora Creek and east of Tuscarora, Md., were down-dropped along such faults. The Araby Formation in the footwall of the normal fault east of Tuscarora is truncated by a northwest-striking normal fault concealed beneath alluvium of the Potomac River. At the Monocacy Natural Resources Area, the Reston and Poolesville Members of the Manassas Sandstone were down-faulted against rocks of the Ijamsville Phyllite and Urbana Formation. The present erosion level provides an opportunity to walk along the Triassic unconformity within and north of the Monocacy River. These exposures provide evidence that Mesozoic faulting and the areal extent of Triassic rocks were more extensive. Northwest-trending normal faults that cut the Sugarloaf Mountain Quartzite and Frederick Formation also support the concept that rocks of the Piedmont, Frederick Valley, and Blue Ridge were also affected by Mesozoic extensional faulting. The diabase dike swarm that trends northward through the eastern part of the map area reflects east-west extension at roughly 200 Ma.

METAMORPHISM

Westminster Terrane

Rocks of the Westminster terrane had a complex metamorphic history under greenschist-facies conditions. The Ijamsville Phyllite contains varying proportions of muscovite-chlorite-paragonite-quartz-magnetite, and calcite, of a first metamorphic event. In fault zones, the phyllites have been retrogressively metamorphosed and sheared into phyllonitic diaphthorites (Knopf, 1931). Such rocks are characterized by "sick-looking" (Knopf, 1931) retrograde chlorite and recrystallized quartz. Abundant leucoxene in these rocks also suggests retrogressive metamorphism (Stose and Stose, 1946; Scotford, 1951; Hopson, 1964). Ijamsville Phyllite locally contains static chloritoid that grew after the deformation or is related to a later prograde metamorphic event.

Rocks of the Sugarloaf Mountain Anticlinorium, Frederick Valley Synclinorium, and Blue Ridge-South Mountain Anticlinorium

The Sugarloaf Mountain Quartzite and Urbana Formation are at chlorite-grade resulting from a single greenschist-facies metamorphic event. The matrix of the quartzites is rich in sericite and contains sparse chlorite porphyroblasts. Cleavage in metagraywacke and metasiltstone of the Urbana Formation is marked by aligned minute sericite crystals. The metasiltstone contains abundant chlorite porphyroblasts that locally give them a green hue.

The Harpers, Antietam, Tomstown, Araby, Frederick, and Grove Formations contain sparse tiny crystals of sericite and minor chlorite porphyroblasts, both of which are crudely aligned on the cleavage.

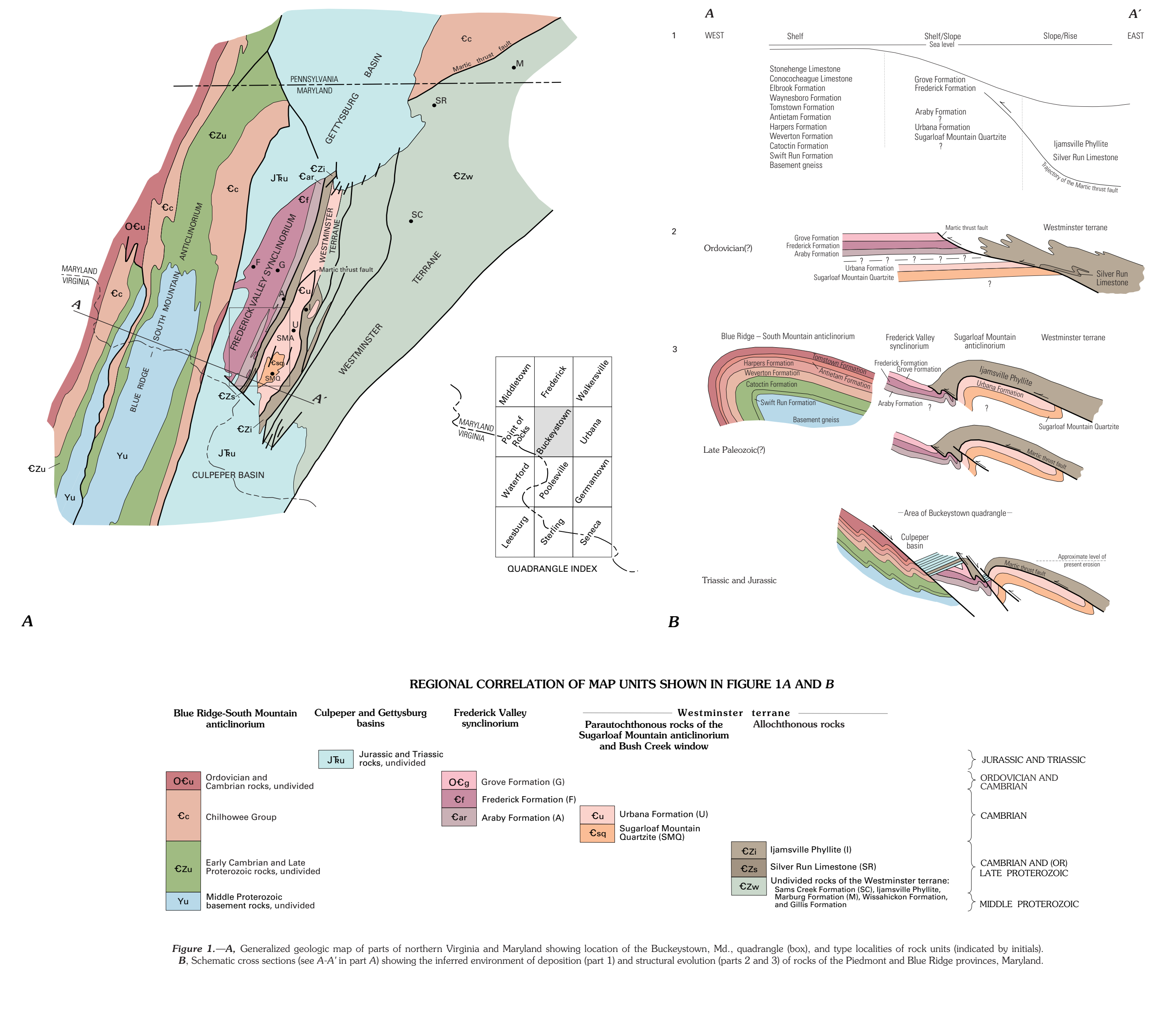
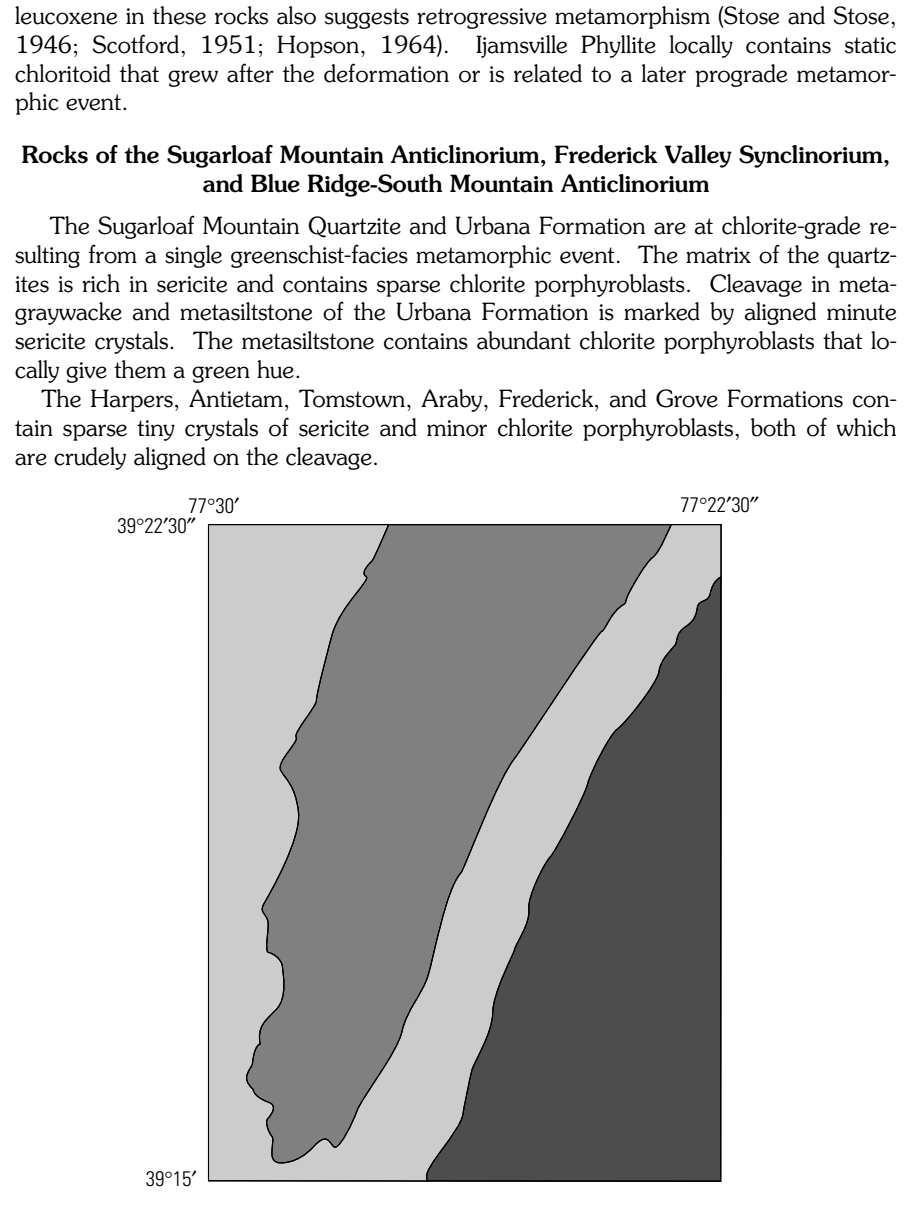


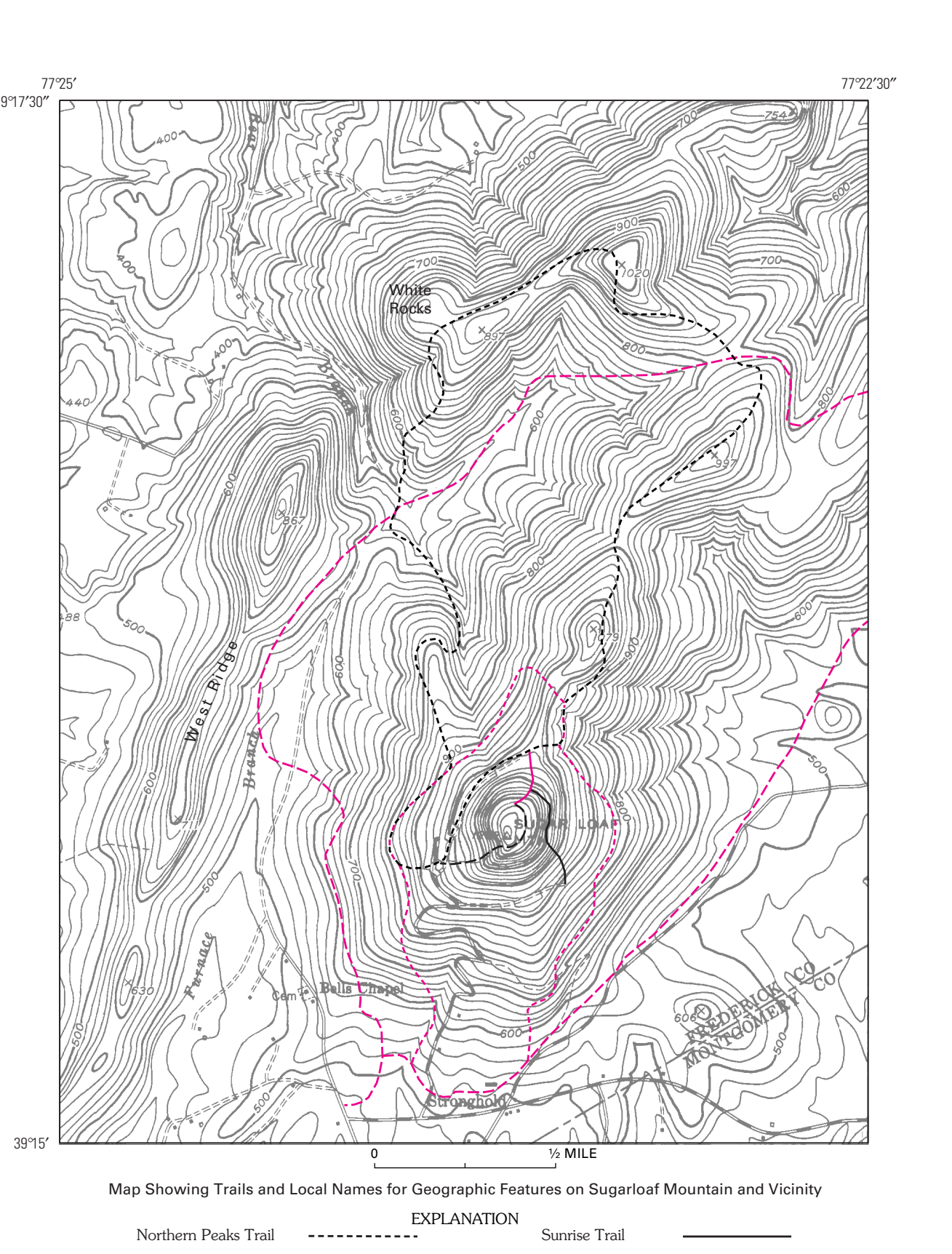
Figure 1.—***A,*** Generalized geologic map of parts of northern Virginia and Maryland showing location of the Buckeystown, Md., quadrangle (box), and type localities of rock units (indicated by initials). ***B***, Schematic cross sections (see *A-A′* in part *A*) showing the inferred environment of deposition (part 1) and structural evolution (parts 2 and 3) of rocks of the Piedmont and Blue Ridge provinces, Maryland.



Index to Areas of Geologic Mapping Responsibility

EXPLANATION

- Southworth
- Brezinski
- Southworth and Brezinski



Map Showing Trails and Local Names for Geographic Features in Sugarloaf Mountain and Vicinity

Table 1.—Major (top) and minor (bottom) element chemical analysis of Late Proterozoic(?) and Lower Cambrian(?) phyllite of the Ijamsville Phyllite (sample 1, lab. no. W–256125) west of Hope Hill in the Buckeystown, Md., quadrangle (N. 39 ° 20′, W. 77° 24′).

[Major elements (in weight percent) determined by X-ray spectroscopy by D.F. Siems and J.S. Mee; minor elements (in parts per million) by Instrumental Neutron Activation Analysis (INAA) by G.A. Wandless and J.N. Grossman, in laboratories of the U.S. Geological Survey]

SiO_2	54.6
Al_2O_3	21.5
Fe_2O_3	8.55
FeO	3.2
MgO	1.53
CaO	.18
Na_2O	1.66
K_2O	3.24
H_2O^+	4.0
H_2O^-	.36
TiO_2	.98
P_2O_5	.18
MnO	.06
CO_2	< .01
Sum	100.05
Sc	22.5
Cr	75.8
Co	25.3
Ni	53
Zn	127
As	2.46
Se	<2
Rb	138
Sr	165
Zr	170
Mo	<2
Sb	.68
Cs	4.94
Ba	778
La	73.2
Ce	146.6
Nd	61.2
Sm	14.32
Eu	2.51
Tb	1.90
Yb	5.50
Lu	.757
Hf	4.58
Ta	1.50
Au	<6
Th	14.01
U	2.51

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GEOLOGIC MAP OF THE BUCKEYSTOWN QUADRANGLE, FREDERICK AND MONTGOMERY COUNTIES, MARYLAND, AND LOUDOUN COUNTY, VIRGINIA

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