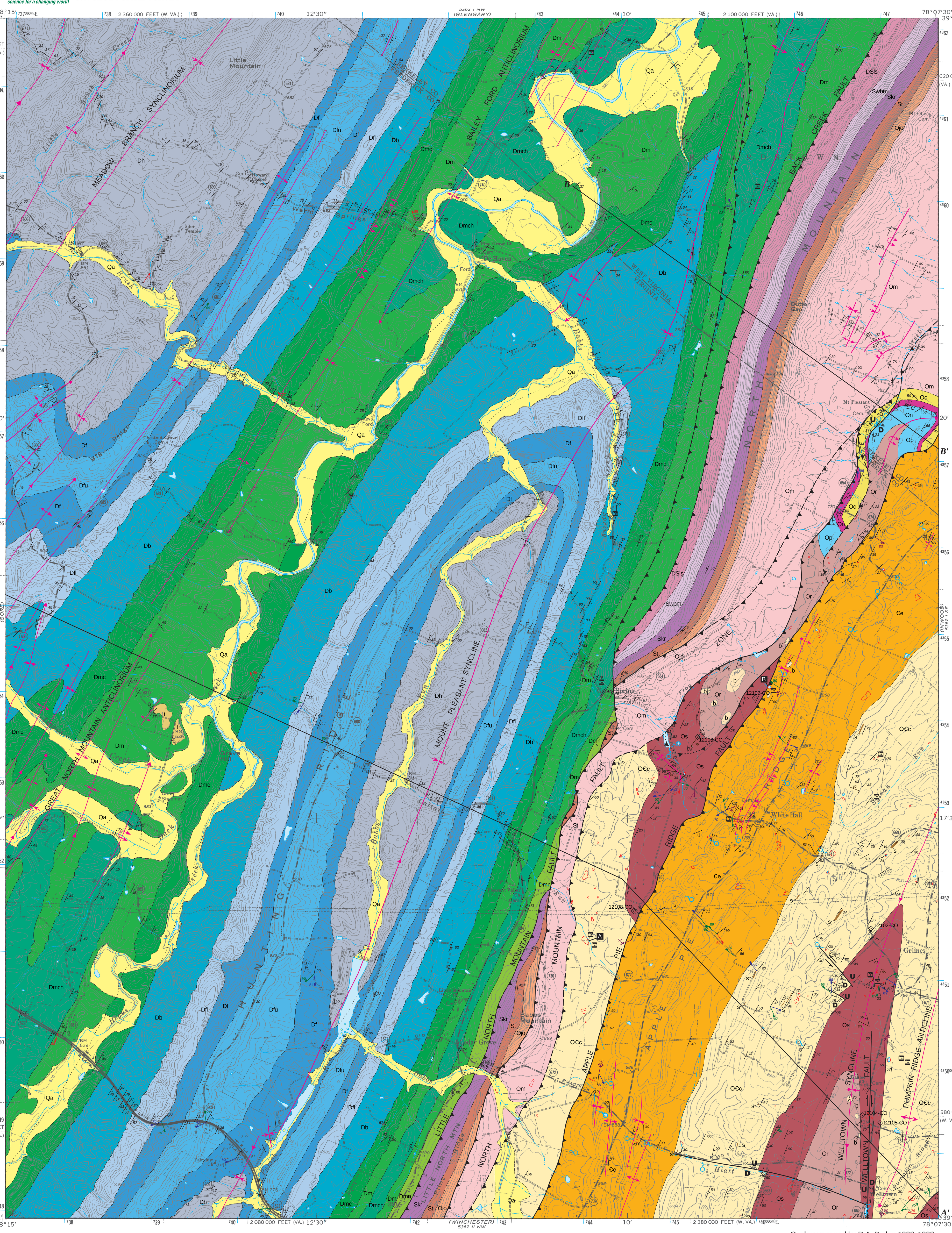
U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

OPEN-FILE REPORT
OF 2010-1265



Base from U.S. Geological Survey, 1965
Polyconic projection. 1927 North American datum
10,000-foot grid ticks based on Virginia coordinate system, north zone
1,000-meter Universal Transverse Mercator grid ticks, zone 17, shown in blue

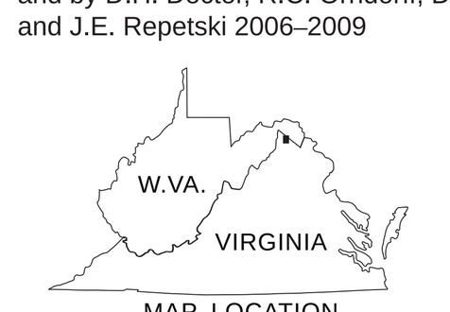
To place on the predicted North American datum 1983 move the projection lines 7 meters south and 23 meters west as shown by dashed corner ticks

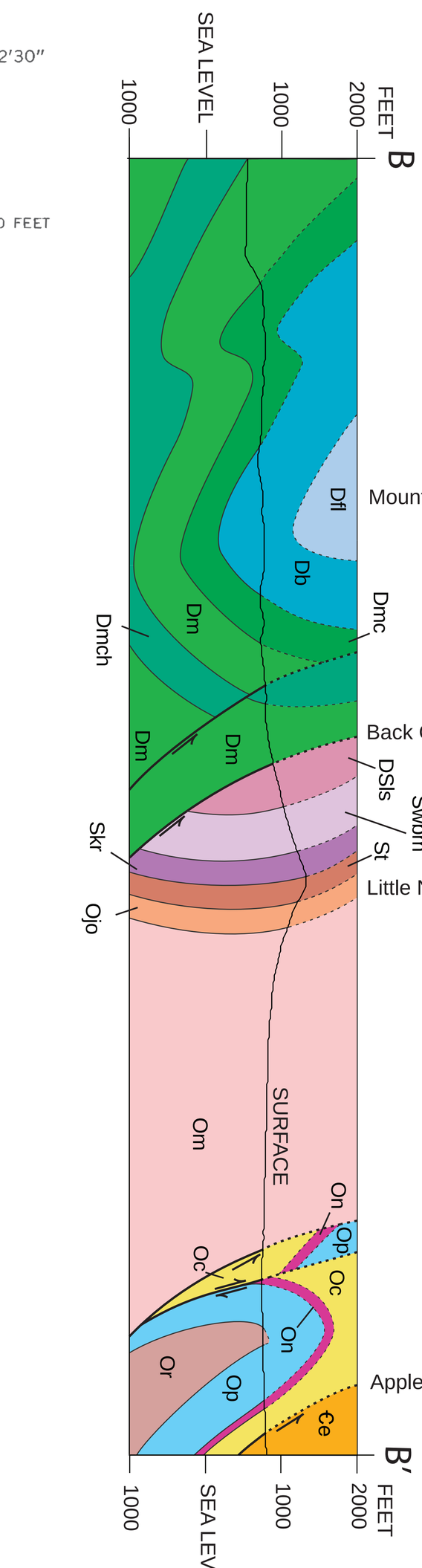
APPROXIMATE MEAN DECLINATION, 2007

SCALE 1:24 000

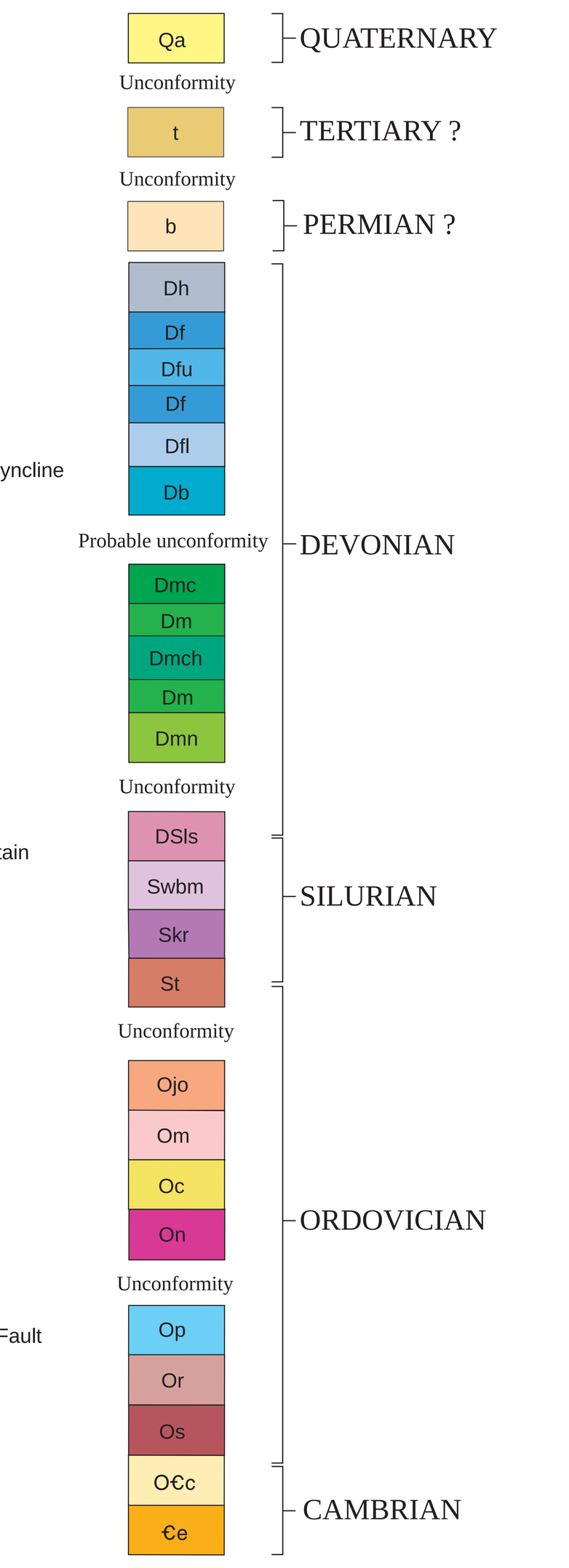
CONTOUR INTERVAL 20 FEET

Geology mapped by R.A. Parker 1992–1993, and by D.H. Doctor, R.C. Orndorff, D.J. Weary, and J.E. Repetski 2006–2009





CORRELATION OF MAP UNITS



EXPLANATION OF MAP SYMBOLS

Bedrock contacts -- Dashed where approximately located; dotted where concealed
Alluvial contacts -- Identity and existence certain, location inferred

Faults -- Dashed where approximately located, dotted where concealed

Thrust fault -- teeth on hanging wall

Strike-slip fault -- arrows indicate relative sense of movement

Normal fault -- U, upthrown side; D, downthrown side

In cross sections, relative sense of movement is shown by arrows, and by:
⊖ away from observer
⊕ toward observer

Strike and dip of beds

Inclined

Vertical

Overturned

Inclined; multiple observations at single point

Overturned; multiple observations at single point

Strike and dip of joints--Point of observation at intersection of multiple symbols

Inclined; widely spaced (spacing >1m)

Inclined; moderately spaced (spacing >0.3m and <1m)

Inclined; closely spaced (spacing <0.3m)

Vertical; moderately spaced

Strike and dip of cleavage

Inclined

Inclined; multiple observations at single point

Vertical; multiple observations at single point

Strike and dip of tension gash

Vertical

Inclined; multiple observations at single point

Vertical; multiple observations at single point

Folds -- Showing trace of axial surface; large arrowhead indicates direction of plunge. Dashed where approximately located

Syncline

Anticline

Overturned syncline

Overturned anticline

Spring -- Tail indicates direction of flow

Sinkhole

Conodont fossil locality -- Showing collection number; sample information is linked to locality in the digital geodatabase.

Photograph location -- Images are included in the digital geodatabase and linked to locality. A and B refer to sites shown in Figure 2

DESCRIPTION OF MAP UNITS

Qa — **Alluvium (Holocene and Pleistocene?)**—Clay, silt, and lesser sand with angular to subrounded clasts, derived from local bedrock. Pebble-size (4–64 mm) fragments of sandstone, siltstone, quartzite and weathered shale are scattered throughout the deposits. In area underlain by the Martinsburg Formation, consists of light-olive-gray, yellowish-gray, and pale-yellowish-orange, well-bedded to crudely bedded, planar-bedded clayey silt, with weathered shale fragments as much as an inch long. Thickness as much as 40 ft

t — **Terrace deposits (Tertiary?)**—Rounded to subrounded, highly weathered cobbles, sand, silt, and clay exposed along State Route 681 near the confluence of Isaacs Creek and Back Creek

b — **Breccia (Permian?)**—Brecciated massive dolomite or dolomitized limestone; may be silicified in places and contain black stringers or staining (Fe-Mn oxide?). Exposures occur in fields east of Frog Hollow and along the axis of the Welltown syncline

Dh — **Hampshire Formation (Upper Devonian)**—Sandstone, mudstone, siltstone, and minor shale. Sandstone, reddish-gray to brownish-gray, medium- to thick-bedded, in part micaceous and (or) arkosic, commonly crossbedded, unfossiliferous. Mudstone, maroon red, weathers into small lumps. Siltstone and shale, reddish-brown to gray, exhibits strong cleavage. Exposed thickness of unit as much as 850 ft. Upper part of formation not exposed in quadrangle. Lower contact placed at base of red-beds and at top of highest gray, fossiliferous sandstone and shale of the underlying Foreknobs Formation

Dfu, Df, Dfl — **Foreknobs Formation (Upper Devonian)**—Interbedded sandstone, siltstone, and minor shale; locally fossiliferous. The main unit (Df) contains coherent packages of thick-bedded to massive sandstone which occur as two ridge-forming units that are mappable throughout the study area. The upper ridge-forming unit (Dfu) consists of 5 to 6 masses of thick, resistant interbedded sandstone, siltstone, and shale that form a prominent ridge in the upper part of the formation; locally two or more masses form distinct ridges. The lower ridge-forming unit (Dfl) consists of 3 to 4 packages of thick-bedded to massive resistant interbedded sandstone, siltstone, and shale which form a prominent ridge at the base of the formation. The interval (Df) between the two ridge-forming units consists of thin- to medium-bedded sandstone, siltstone, and shale and typically occupies the drainage area between the two ridges; commonly not well exposed. The lower contact with the Brallier Formation is gradational through about 300 ft and is mapped where an abrupt increase in fossiliferous sandstone beds greater than 6 in. occurs. Thickness about 1,700 ft

Db — **Brallier Formation (Upper Devonian)**—Interbedded shale, siltstone, and sandstone, dark-gray to greenish-gray, weathers light brownish-gray, sparsely fossiliferous. Grain size increases irregularly upward in section; sandstone beds, 2 to 6 in. thick, become more abundant near top of formation. Shale that is thickly laminated with scattered siltstone beds up to 3 in. thick makes up the bulk of the formation. The lower contact with the underlying Mahantango Formation is a disconformity above a massive sandstone unit (Dmc) at the top of the Mahantango. A mappable contact is placed at the top of this sandstone. Thickness approximately 1,100 ft

Dmc, Dm, Dmch — **Mahantango Formation (Middle Devonian)**—Mudstone, shale, siltstone, and minor sandstone. Mudstone, dark-gray to olive-gray, hackly weathering, locally very fossiliferous; bedding obscure, spheroidal weathering common. Sandstone (Dmc, equivalent to Clearville Siltstone Member of Jolley, 1983), medium-gray, fine-grained, medium- to thick-bedded, generally massive, locally fossiliferous; occurs as two units near top of formation separated by mudstone; total thickness as much as 380 ft. Chaneysville Siltstone Member (Dmch) is predominantly massive darkgray siltstone and black mudstone occurring in the lower part of the formation, locally fossiliferous, up to 850 ft thick, grades into calcareous shale at base. Total thickness of entire formation ranges from 1,600 to 1,800 ft. Lower contact gradational; placed at base of olive-gray beds above underlying Marcellus Shale

Dmn — **Marcellus Shale and Needmore Shale, undivided (Middle and Lower Devonian)**—Black shale, silty shale, calcareous shale, and minor limestone. Thickness as much as 800 ft; however, units are not well exposed in the quadrangle due to faulting and colluvial cover. Descriptions below are based upon mapping conducted in adjacent quadrangles

Marcellus Shale (Middle Devonian)—Shale, black to dark-gray, highly fissile, with localized beds or concretions of dark-gray, argillaceous limestone or calcareous shale. Forms thin, platy chips and weathers dusky yellowish-gray in exposed outcrops. Base of Marcellus is marked regionally by the Tioga Metabentonite; not seen in outcrops but may be present in covered intervals. Thickness up to 700 ft

Needmore Shale (Middle and Lower Devonian)—Calcareous shale, dark-greenish-gray to olive-gray, and dark-gray fissile silty shale; locally fossiliferous. Thickness about 100 ft. Grades upward into the Marcellus Shale through a series of thin limestone beds. Base placed at top of coarse sandstone of underlying Oriskany Sandstone.

DSls — **Oriskany Sandstone, Helderberg Group, and Tonoloway Limestone, undivided (Lower Devonian and Upper Silurian)**—Sandstone, limestone, and shale. Thickness as much as 800 ft; however, units are not well exposed in the quadrangle due to faulting and colluvial cover. Descriptions below are based upon mapping conducted in adjacent quadrangles

Oriskany Sandstone (Lower Devonian)—Sandstone, light-gray, yellowish-gray-, or yellowish-brown-weathering, medium- to coarse-grained, medium- to thick-bedded, locally crossbedded, calcareous; locally conglomeratic with quartz pebbles up to 0.5 in. long; friable when weathered; contains molds of brachiopod shells. Base placed at top of cherty limestone of Licking Creek Limestone of Helderberg Group

Helderberg Group, undivided (Lower Devonian and Upper Silurian)—Limestone, medium- to dark-gray, fine-grained, irregularly bedded, fossiliferous; contains black or light gray to white chert nodules, lenses, and beds as much as 1.5 ft thick near top; some limestone is medium gray, coarse grained, crinoidal. Individual units cannot be distinguished in the quadrangle due to faulting and colluvial cover. Lower contact placed at base of crinoidal limestone overlying shaly, laminated limestone of the Tonoloway Limestone based on mapping in other areas

Tonoloway Limestone (Upper Silurian)—Limestone and shale. Limestone, medium-gray to medium dark-gray, crinkly laminated to thin-bedded. Shale, medium-gray to dark-gray, calcareous. Locally contains ripple marks and mud cracks. Base placed at top of Tavenner Sandstone Member (Butts and Edmundson, 1966) of the Wills Creek Formation (not exposed in quadrangle)

Swbm — **Wills Creek Formation, Bloomsburg Formation, and McKenzie Formation, undivided (Upper and Lower Silurian)**—Shale, sandstone, siltstone, and limestone. Thickness as much 275 ft

Wills Creek Formation (Upper Silurian)—Interbedded shale, siltstone, limestone, and sandstone. Shale, medium-dark-gray and greenish-gray to light-olive-gray, weathers yellowish-gray to reddish-gray, crinkly laminated, calcareous. Siltstone, greenish-gray to gray, weathers dark brownish-gray or grayish-yellow. Limestone, medium-dark-gray to olive-gray, very fine grained with local interclastic flat-pebble conglomerate. Sandstone primarily near top of unit, massive weathering, crossbedded, 15 to 20 ft thick, named Tavenner Sandstone Member by Butts and Edmundson (1966). Thickness of formation 140 to 180 ft

Bloomsburg Formation (Upper Silurian)—Interbedded sandstone, siltstone, mudstone, and shale. Sandstone, reddish-brown to grayish-red, and gray, fine- to medium-grained, thin- to thick-bedded. Siltstone, grayish-red, reddish-brown, grayish-purple, medium-gray, light-olive-gray, and greenish-gray, thin- to medium-bedded, shows prominent cleavage. Mudstone maroon-red, weathers dusky pale red, forms cohesive lumps in outcrop. Shale, gray, greenish-gray, and reddish-brown. Lower contact is at base of red sandstone beds

McKenzie Formation (Upper and Lower Silurian)—Shale and siltstone. Shale, yellow-tan with silky luster, olive-gray and light-olive-gray, fissile, and fossiliferous. Siltstone, yellow-gray, calcareous

Skr — **Keefer Sandstone and Rose Hill Formation, undivided (Lower Silurian)**—Quartzite, sandstone, and shale. Thickness approximately 500 ft

Keefer Sandstone—Quartzite, medium-light-gray, coarse-grained to pebbly, massive, vitreous at base, grading up to medium-gray, medium-grained, and olive-gray, fine-grained. Thickness about 130 ft

Rose Hill Formation—Sandstone and shale. Sandstone, reddish-brown, grayish-red, grayish-purple, and gray, medium- to coarse-grained, medium- to thick-bedded. Shale, gray, greenish-gray, and reddish-brown, locally silty, and hackly weathering, locally fossiliferous. Lower contact placed at base of red sandstone overlying massive quartzite ledges of Tuscarora Quartzite. Thickness about 370 ft

St — **Tuscarora Quartzite (Lower Silurian)**—Quartzite, light- to medium-gray, medium- to coarse-grained, thick-bedded, some beds conglomeratic. Base placed at bottom of quartzite ledges. Thickness about 250 ft

Ojo — **Juniata Formation and Oswego Sandstone, undivided (Upper Ordovician)**-Sandstone, shale, and conglomerate. Thickness about 250 ft

Juniata Formation—Sandstone and shale. Arkosic sandstone, grayish-red to brown, fine- to coarse-grained, thin- to medium-bedded, locally thick-bedded, crossbedded. Shale or mudrock, grayish-red; occurs as thin beds and partings, mostly near top of formation

Oswego Sandstone—Sandstone and conglomerate. Sandstone, greenish-gray, coarse-grained, thick-bedded, conglomeratic. Conglomerate, interbedded with sandstone, composed of rounded clasts of chert and sandstone. Sandstone friable where locally calcareous and fossiliferous

Om — **Martinsburg Formation (Upper and Middle Ordovician)**—Interbedded shale and lesser graywacke-siltstone and graywacke-sandstone. Shale, medium-gray to dark-gray and light-olive-gray, weathers grayish-orange and dark yellowish orange, commonly silty, generally noncalcareous, although calcareous intervals occur in lower part of formation (Stickley Run Member). Siltstone and sandstone (immature, generally lithic graywacke), medium-gray, grayish orange weathering, very fine to fine-grained, commonly graded (fining upward), lenticular, slightly calcareous to noncalcareous; contains many small crossbeds. Graywacke is more abundant and more thickly bedded higher in section where it forms conspicuous ribs in creek beds and may constitute as much as 30 percent of some intervals that are several hundred feet thick. Thicker beds are generally graded and display characteristics of complete Bouma cycles. Regional thickness may be more than 5,000 feet

Oc — **Chambersburg Formation (Middle Ordovician)**—Interbedded limestone and calcareous shale. Limestone, medium-gray to medium-dark-gray, fine- to medium-grained, thin- to thick-bedded, irregularly bedded, knobby weathering. Calcareous shale, medium-dark-gray to very dark-gray. Thickness as much as 500 ft

On — **New Market Limestone (Middle Ordovician)**—Limestone, medium-gray and dove-gray, weathers very light-gray, thick-bedded, micritic, fenestral. Lower 10 ft is medium-gray to light-gray, thin-bedded dolomitic limestone interbedded with light-gray dololaminite. Base placed at top of uppermost medium-gray, thick-bedded dolostone of Pinesburg Station Dolomite (Op) and below dolomitic limestone of the New Market. Exposed thickness approximately 160 ft

Op — **Pinesburg Station Dolomite (Middle Ordovician)**—Dolostone and dololaminite, medium- to light-gray, weathers buff-yellow to very light-grey, fine-grained, thick-bedded to massive, with minor white and light-gray chert nodules. Weathered surfaces exhibit "butcher-block" (cross-hatched joints) structure. Also contains a few thin, medium-gray, fine-grained limestone beds in lower part. Paleokarst features of irregular bedding and collapse breccia common near top of unit; breccia may be silicified, with localized iron mineralization. Lower contact placed at base of lowermost light-gray, thick-bedded dolostone overlying dominantly limestone cycles of the Rockdale Run Formation. Exposed thickness as much as 700 ft

Or — **Rockdale Run Formation (Middle and Lower Ordovician)**—Interbedded limestone and dolostone. Limestone, bluish-gray, medium-gray, and dark-gray, fine- to medium-grained, thin- to medium-bedded, fossiliferous. Dolostone, medium-gray, fine- to medium-grained, medium-bedded, crystalline. Lithologies occur as fining upward carbonate cycles capped by dololaminite beds as much as 2 ft thick. Limestone beds also contain intraformational conglomerates, algal bioherms, bioclastic zones, and burrow mottling. Gastropod *Lecanospira* is common in lower and middle parts of formation. Lower contact placed at base of lowermost crystalline dolostone or dololaminite bed overlying dark-gray, thick-bedded limestone of the Stonehenge Limestone. Exposed thickness approximately 1,200 ft; thickness uncertain due to faulting and folding

Os — **Stonehenge Limestone (Lower Ordovician)**—Limestone, dark-gray, fine- to medium-grained, thick-bedded to massive, fossiliferous, with crinkly laminations and minor black chert. Also contains algal bioherms, intraformational conglomerates, bioclastic beds, and minor dolostone beds. Gastropod *Lecanospira* is common in middle part of formation. Massive limestone may show mottles from dolomitic burrows. Contact with underlying Conococheague Limestone is gradational; base placed at first dark-gray limestone with crinkly siliceous laminations (Stoufferstown Member) and above the uppermost dolostone that caps Conococheague carbonate cycles. Thickness approximately 770 ft

O€c, s — **Conococheague Limestone (Lower Ordovician and Upper Cambrian)**—Interbedded limestone, dolostone, dololaminite and sandstone. Limestone, medium-gray, fine-grained, thin- to medium-bedded. Dolostone and dololaminite, light-gray, fine-grained, medium-bedded. Sandstone, light-gray to buff, orange-reddish weathering, medium- to coarse-grained, calcareous. Limestone lithologies include intraformational conglomerates, algal bioherms, ribbon rock, and oolites. Lithologies occur as carbonate cycles. Lower 295 ft, Big Spring Station Member, consists of gray to buff, orange-reddish weathering, coarse-grained calcareous sandstone; medium-gray, fine-grained limestone with intraformational conglomerate; and light-gray, fine-grained dolostone. Sandstone beds (s) also occur in middle part of formation and form ridges. Upper part of formation contains very light-gray weathering, medium-gray limestone with thin siliceous laminae. Base placed below lowermost calcareous sandstone bed of Big Spring Station Member. Thickness is approximately 2,800 ft

€e — **Elbrook Formation (Middle Cambrian)**—Interbedded limestone, dolostone, and shale. Limestone, medium-gray, fine- to medium-grained, thin- to medium-bedded. Dolostone, light- to medium-gray, yellowish weathering, fine-grained, medium-bedded. Shale, gray, yellowish weathering, dolomitic. Limestone contains algal bioherms, intraformational conglomerates, and dolomitic burrow mottles. Lowest beds exposed are bluish-gray, medium- to thick-bedded limestone with dolomite ribbons and mottles and medium-gray, thick-bedded dolostone of the middle part of formation. Cycles of bluish-gray algal limestone and grainstone and light-gray argillaceous dolostone occur in upper part of Elbrook. A distinctive lithology is yellowish weathering, thin-bedded dololaminite that appears shaly in weathered outcrops. Thickness is at least 2,500 ft; the thickness is increased by intraformational folding

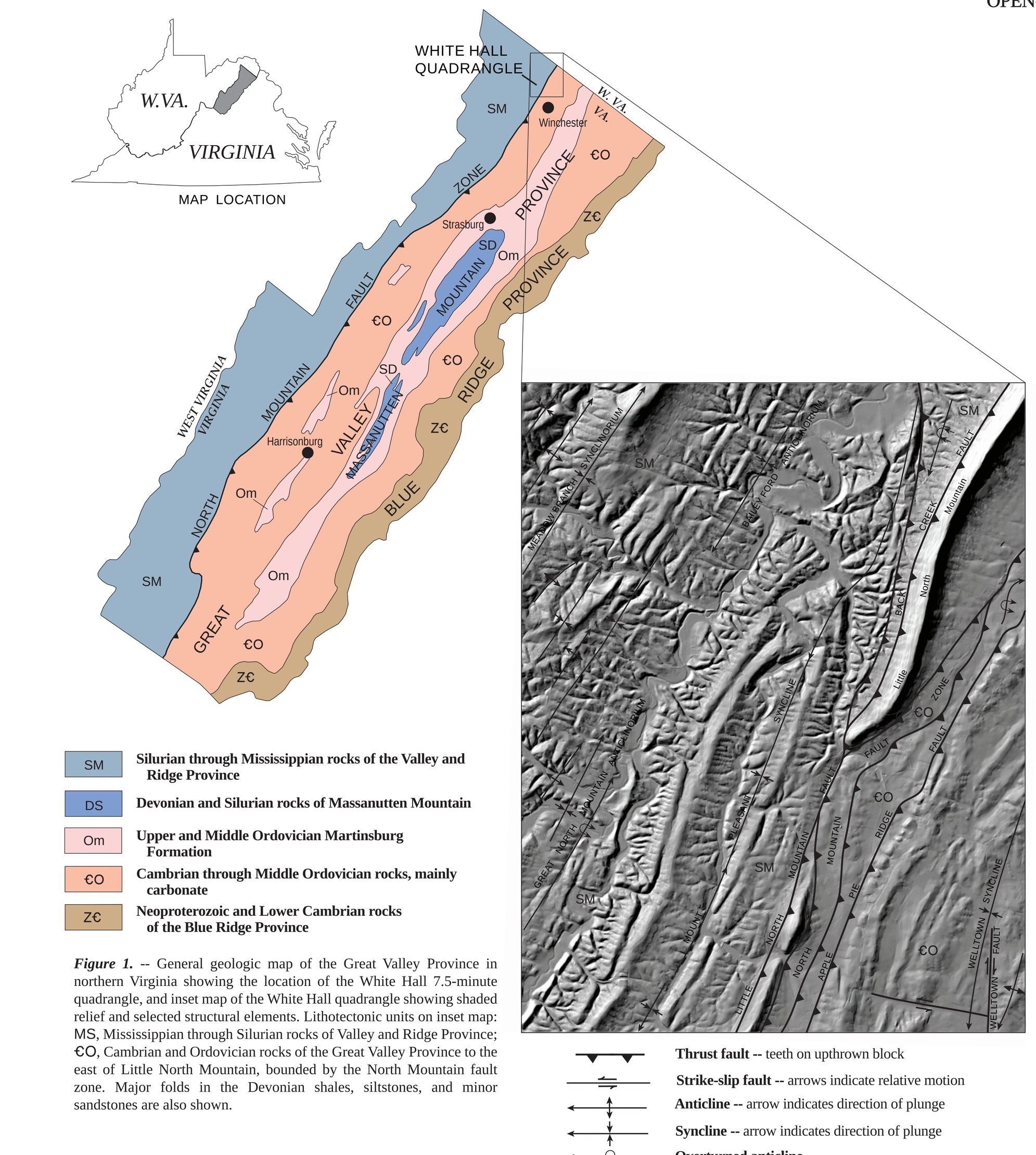
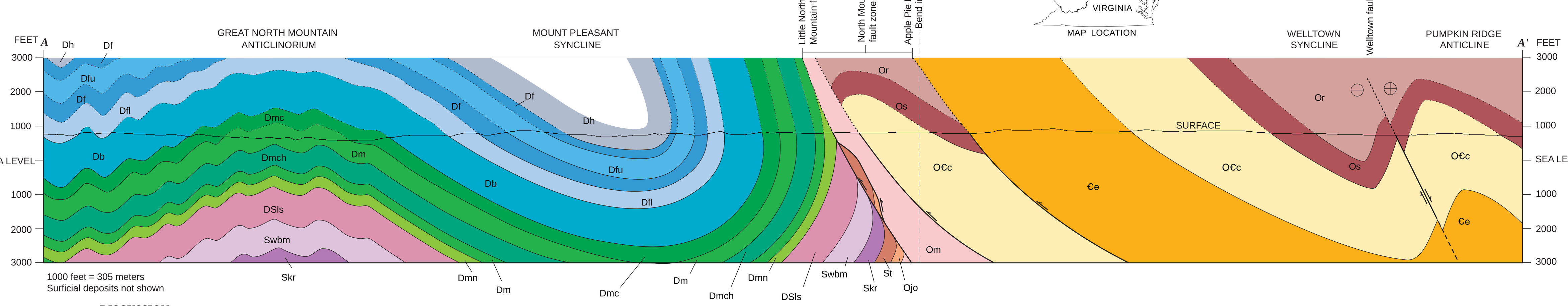
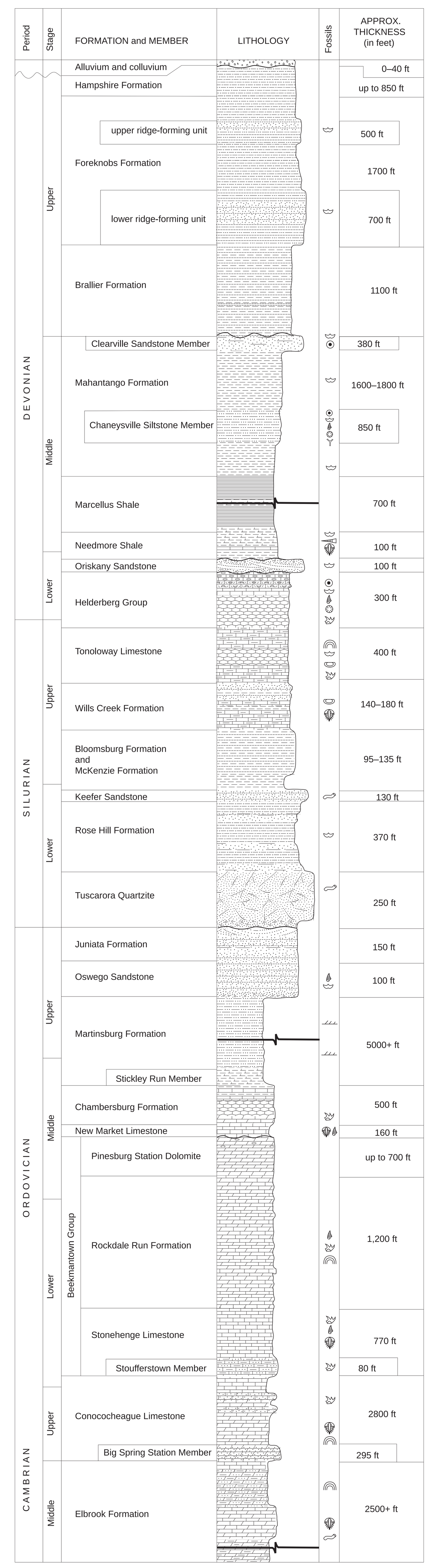


Figure 1. -- General geologic map of the Great Valley Province in northern Virginia showing the location of the White Hall 7.5-minute quadrangle, and inset map of the White Hall quadrangle showing shaded relief and selected structural elements. Lithotectonic units on inset map: MS, Mississippian through Silurian rocks of Valley and Ridge Province; €O, Cambrian and Ordovician rocks of the Great Valley Province to the east of Little North Mountain, bounded by the North Mountain fault zone. Major folds in the Devonian shales, siltstones, and minor sandstones are also shown.



STRATIGRAPHIC COLUMN EXPLANATION



Regional unconformity

Major fault zone

LITHOLOGIC PATTERNS

Alluvium and colluvium
Sandy or silty shale
Interbedded sandstone and siltstone
Interbedded siltstone and shale
Bedded sandstone
Argillaceous or shaly sandstone
Clay or clay shale
Silt, siltstone, or shaly silt
Carbonaceous shale
Calcareous shale
Crossbedded sandstone
Conglomerate
Cherty limestone
Fossiliferous clastic limestone
Limestone
Nodular or irregularly bedded limestone
Argillaceous or shaly limestone
Quartzite
Crossbedded subgraywacke
Interbedded limestone and shale
Dolomitic limestone
Cherty dolomite
Dolomite
Silty limestone
Sandy limestone
Sandy dolomite
Silty dolomite
Argillaceous or shaly dolomite

COMMONLY OCCURRING FOSSILS

Brachiopods
Gastropods
Corals
Bryozoans
Crinoids
Burrows
Ostracodes
Graptolites
Nautiloids
Trilobites
Conodonts
Stromatolites

UNIT CONVERSION FACTORS

1 inch (in.) = 25.4 millimeter (mm)
1 foot (ft) = 0.3048 meter (m)
1 mile (mi) = 1.609 kilometer (km)

1 cubic foot per second (cfs) = 0.02832 cubic meter per second (m^3/sec)

DISCUSSION

INTRODUCTION

The White Hall quadrangle is located within the Valley and Ridge province of northern Virginia and the eastern panhandle of West Virginia. The quadrangle includes the physiographic regions of the northern Great Valley to the southeast, the narrow ridge of Little North Mountain along the western edge of the Great Valley, and the broad region of elongated valleys and ridges east of Little North Mountain. Early geologic mapping in the White Hall quadrangle was conducted by Butts and Edmundson (1966), who mapped the Frederick County, Va., portion at a scale of 1:62,500. Lessing and others (1994) mapped the West Virginia portion of the quadrangle at a scale of 1:24,000. Dean and others (1994) and Lessing and others (1994) refer to the prominent curvilinear ridge extending into the northeast corner of the quadrangle as North Mountain, whereas Butts and Edmundson (1966) refer to it as Little North Mountain. Despite the label of North Mountain on the topographic base map, this ridge is referred to as Little North Mountain in this report to avoid confusion with Great North Mountain immediately to the southwest and to preserve continuity with the nomenclature of this feature as it extends farther south in Virginia.

STRATIGRAPHY

All exposed bedrock outcrops are sedimentary deposits of Paleozoic age ranging from the Middle Cambrian Period to Late Devonian Period, approximately 515 to 365 Ma. These clastic and carbonate sedimentary strata reflect nearshore and offshore marine and deltaic depositional environments. The deposits indicate minor cyclic sea level transgression and regression along a passive continental margin during the Late Cambrian to Middle Ordovician Periods, to major sea level changes resulting from tectonic uplift during the Late Ordovician part of the Taconian orogeny. Depositional environments (from oldest to youngest) include (1) broad shallow marine shelf represented by the carbonate rocks of the Late Cambrian to Middle Ordovician Periods; (2) continental slope and foreland basin, represented by deposits of shale and turbiditic flysch in the Upper Ordovician; (3) nearshore marine, represented by sandstones, limestones, and shales of the uppermost Ordovician to lower Devonian; (4) marine basin and river delta, represented by siliciclastic shales, siltstones, and minor sandstones of the Early to Late Devonian Periods (Orndorff and others, 1999). These strata account for about 21,700 ft of section.

Topographic ridges in the quadrangle are held up by the resistant sandstones and quartzites in the Tuscarora Quartzite (St) or Keefer Sandstone and Rose Hill Formation (Skr), as on Little North Mountain. Lower ridges west of Little North Mountain are underlain by sandstones in the Foreknobs (Df) or Mahantango (Dm) Formations. East of Little North Mountain, the prominent Apple Pie Ridge is held up by limestone and shaly dolomite of the Elbrook Formation (€e) that has been thrust up along the Apple Pie Ridge fault. Other ridges in the carbonate units are held up by thin sandstone beds within the Conococheague Limestone (O€c) or highly siliceous beds at the base of the Stonehenge Limestone (Os).

Placement of contacts between the Lower Ordovician carbonate rock units were aided by the collection and identification of conodont fossils (Orndorff, 1988). On the east limb of the Welltown syncline the contacts between the Rockdale Run Formation (Or), Stonehenge Limestone, and Conococheague Limestone were placed using the conodont fossil assemblages found at the junction of State Route 672 and Welltown Road, just south of Galilee Church. Conodont fossil assemblages also aided in placing contacts between carbonate units within the carbonate duplex along the North Mountain fault zone.

Surficial materials include unconsolidated alluvium, colluvium, and terrace deposits of Quaternary age, and local paleo-terrace deposits possibly of Tertiary age. Alluvium (Qa) was tentatively mapped along the larger streams; locally, low terraces may exist but have not been broken out within this unit. Colluvium (not mapped) covers most of the steeper slopes and fills the bottoms of many of the mountain hollows; it is composed mainly of quartzite and sandstone boulders and cobbles, or fragments of chert.

STRUCTURE

Tectonic deformation of the bedrock in the White Hall quadrangle took place during the Alleghanian orogeny of the Late Paleozoic Era when the North American continent collided with the continents of Africa and Europe, forming the supercontinent Pangea. Erosion has predominated during the last 280 m.y., resulting in the present landscape.

The quadrangle lies across the northeast plunge of the Great North Mountain anticlinorium (Butts and Edmundson, 1966) and includes several other regional folds. Folds tend to verge to the northwest, reflecting the tectonic transport direction, and trend to the northeast approximately 28º to 30º with gentle plunges to either the north-northeast or south-southwest. The Mount Pleasant syncline, centrally located within the quadrangle, is a doubly-plunging syncline that has steeply dipping overturned beds on the east limb. This is the northernmost extent of a regional syncline that spans all of Frederick County (Butts and Edmundson, 1966). To the north, the southernmost extent of the Bailey Ford anticlinorium plunges out southwestward into a complex series of synclines and anticlines lying parallel to the Mount Pleasant syncline. To the west and southwest, many northeast-plunging folds nose out and represent the northeastern extent of the Great North Mountain anticlinorium and the southwestern extent of the Meadow Branch synclinorium. To the southeast, the main folds are the Welltown syncline and the Pumpkin Ridge anticline; both plunge to the south. A notable anticline plunges to the northeast at the eastern edge of the map area and contains the only exposure of the Middle Ordovician rocks in the quadrangle. After being formed, this anticline subsequently was cut by faults having relatively limited displacement (several thousand feet). The anticline is itself thrust up over the eastern limb of the corresponding syncline; this limb extends to the southwest where it ends at another thrust fault near Green Spring. Outcrop-scale folds are parasitic on regional folds and appear to represent local adjustments during the same phase of folding. Two zones of tight minor folds are evident in the Elbrook Formation, one zone located at the village of White Hall, and the second along Braddock Road. A late-stage cross-strike fault (Orndorff, 1992) is seen along Hiatt Run on the west limb of the Welltown syncline, with smaller faults radiating around the nose of the fold further north.

The North Mountain fault zone cuts through the eastern part of the quadrangle; it is a series of thrust faults generally oriented northeast–southwest that separate the Silurian and Devonian shales, siltstones and sandstones from the Cambrian and Ordovician carbonate rocks and shales (Fig. 1). The North Mountain fault zone widens north of Strasburg, Va. to north of Winchester, Va., and multiple splays of the primary thrust fault are evident in the White Hall quadrangle. The two faults bounding the fault zone are the Little North Mountain fault and the Apple Pie Ridge fault. The Little North Mountain fault lies on the west side of Little North Mountain and brings Silurian and Lower Devonian rocks onto Middle Devonian shales. The Apple Pie Ridge fault (Orndorff and others, 2003) thrusts the oldest rocks exposed in the quadrangle (Elbrook Formation) onto the Lower Ordovician Stonehenge Limestone and Conococheague Limestone. Dean and others (1994) named the thrust splay along the west side of Little North Mountain beginning at Green Spring the Back Creek fault; this is probably the northern extension of the Little North Mountain fault. The Back Creek fault has been traced approximately 24 mi northward from Green Spring into Maryland and converges with the North Mountain fault zone at McCoy's Ferry, Md.; thus, the ridge of Little North Mountain is a large horse (Dean and others 1994). Interruptions in the outcropping of the Tuscarora Quartzite along the Little North Mountain fault likely resulted from cross-strike faulting rather than from thinning of sedimentary strata (Giles, 1942); however, lack of outcrop precludes precise mapping of faults in these areas. A prominent north-south trending fault in the southeast part of the quadrangle area cuts along the east limb of the Welltown syncline, and is herein named the Welltown fault. It is manifested by pronounced thinning of the Stonehenge Limestone and by numerous calcite-filled tension gashes in limestone and shear structures within brecciated dolomite, observable in outcrops along the lineament.

KARST FEATURES AND HYDROLOGY

Karst refers to a type of terrain that develops due to solution of bedrock along groundwater flowpaths, resulting in voids at depth. Features typical of karst terrain include sinkholes and shallow closed depressions (dolines), sinking streams, springs, and caves. Karst development is pervasive in the Cambrian and Ordovician carbonate rocks in the northern Shenandoah Valley (Hubbard, 1983; Orndorff and Goggin, 1994). In the White Hall quadrangle karst development occurs in all of the carbonate rocks. Caves are not prevalent in the quadrangle; only one cave is known and it occurs within the middle limestone of the Elbrook Formation. The cave is a former phreatic passage extending down the dip of bedding for approximately 200 ft, with ephemeral standing water at the bottom. Springs occur mainly near or on faults. It is noteworthy that several perennial springs in the quadrangle were found near the crest of Apple Pie Ridge, especially near zones of tight folding or to the east of southeast-dipping thrust faults. Most of these are smaller springs (<1 cubic foot per second), and several flow over the surface for a short distance before sinking again. The largest springs in the quadrangle are located within the Stonehenge Limestone, southeast of the village of Green Spring. Sinkhole development is concentrated along faults, along the axis of the Welltown syncline, and within the nose and axis of the Pumpkin Ridge anticline; however, sinkholes occur within all of the carbonate rock units, especially where the rocks have undergone locally intensified deformation through folding, faulting, or some combination (see also Hubbard, 1983). Along the North Mountain fault zone, sinkholes pond water as they collect surface runoff in the wet season, although they eventually drain (Fig. 2). Areas of low elevation formed within the carbonate rocks permit rapid internal drainage, and constitute zones of focused groundwater recharge.

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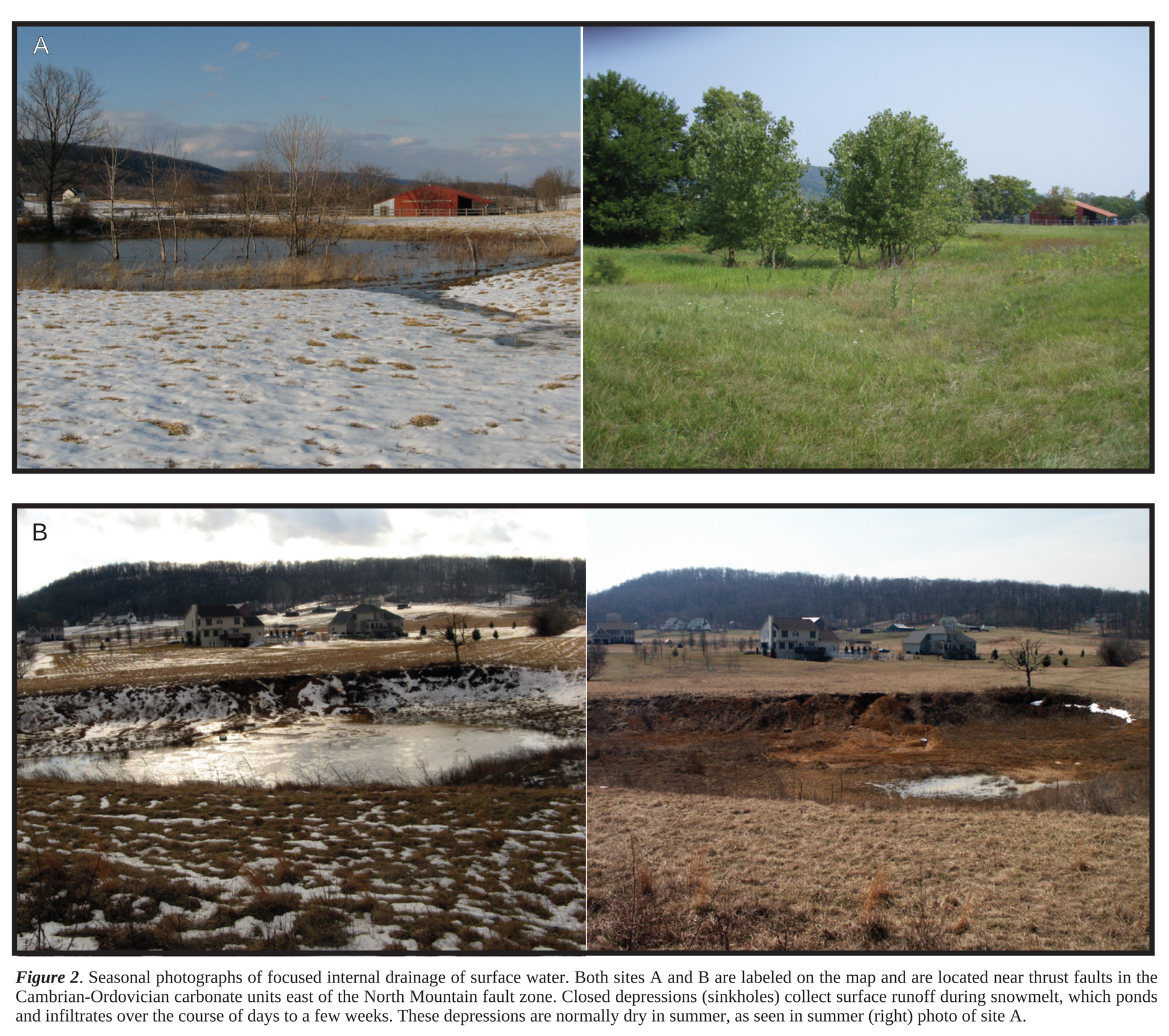
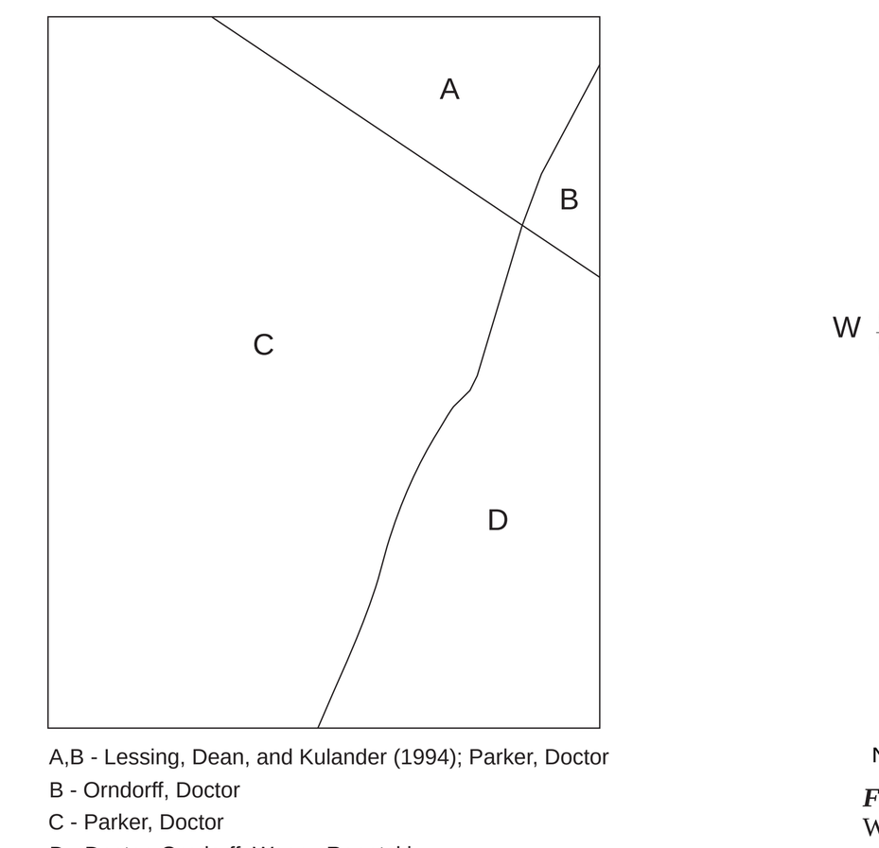
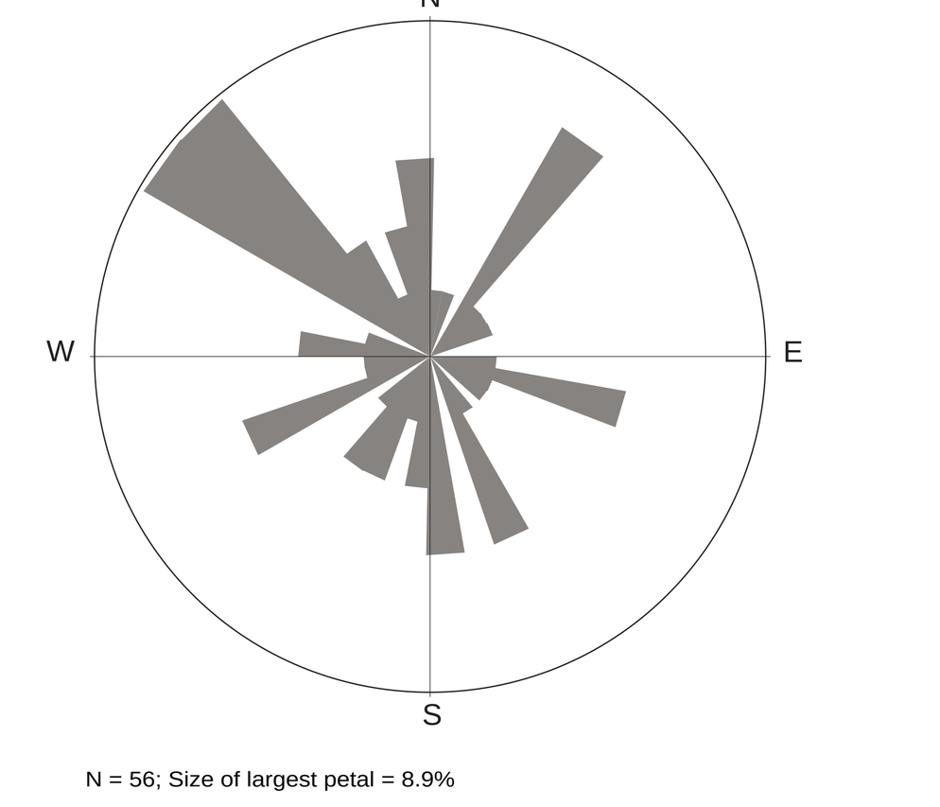


Figure 2. Seasonal photographs of focused internal drainage of surface water. Both sites A and B are labeled on the map and are located near thrust faults in the Cambrian-Ordovician carbonate units east of the North Mountain fault zone. Closed depressions (sinkholes) collect surface runoff during snowmelt, which ponds and infiltrates over the course of days to a few weeks. These depressions are normally dry in summer, as seen in summer (right) photo of site A.

MAPPING RESPONSIBILITY



A,B - Lessing, Dean, and Kulander (1994); Parker, Doctor
B - Orndorff, Doctor
C - Parker, Doctor
D - Doctor, Orndorff, Weary, Repetski



N = 56; Size of largest petal = 8.9%

Figure 3.—Equal area Rose diagram of joint orientations in the White Hall quadrangle. Petals represents joint azimuths binned in 10º increments, dip to right of azimuth.

GEOLOGIC MAP OF THE WHITE HALL QUADRANGLE, FREDERICK COUNTY, VIRGINIA, AND BERKELEY COUNTY, WEST VIRGINIA

By
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