**EXPLANATION** 

Interbedded sandstone and siltstone

Argillaceous or shaly sandstone

Interbedded sandstone, siltstone, and shale

Alluvium and colluvium

Sandy or silty shale

Bedded sandstone

Clay or clay shale

Calcareous shale

Limestone

Crossbedded sandstone

Fossiliferous clastic limestone

Argillaceous or shaly limestone

Crossbedded subgraywackee

Dolomitic limestone

Sandy dolomite

Silty dolomite

Regional unconformity

— Major fault zone

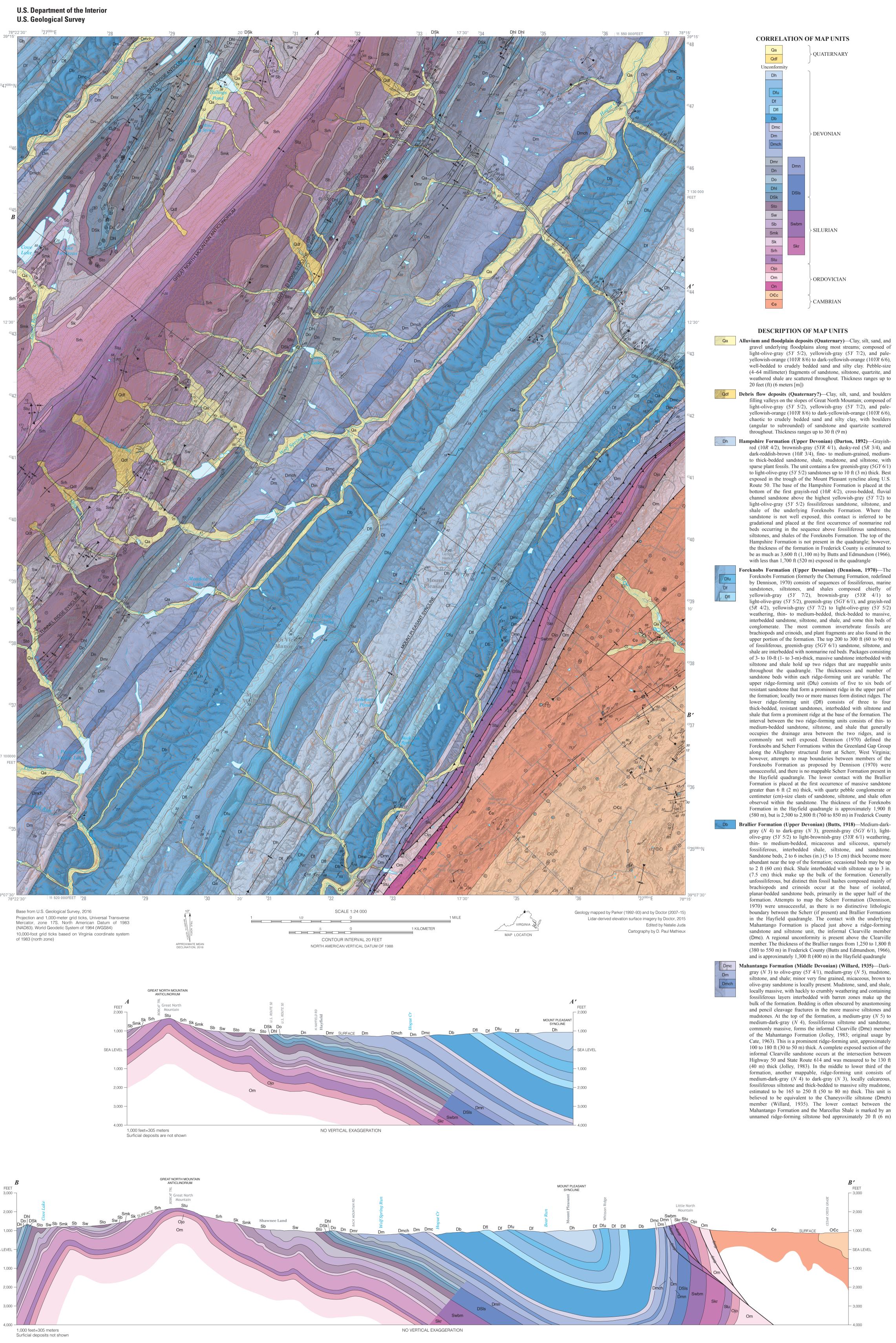
Argillaceous or shaly dolomite

Interbedded limestone and shale

Nodular or irregularly bedded limestone

Silt, siltstone, or shaly silt

Lithologic patterns





## DISCUSSION

The Hayfield 7.5-minute quadrangle is located within the Valley and Ridge physiographic province of northern Virginia. The quadrangle includes the topographical lowland area 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 west of Little North Mountain (fig. 1). The most prominent physiographic feature within the quadrangle is Great North Mountain, which extends across the northwestern portion of the quadrangle.

STRATIGRAPHY All exposed bedrock units are Paleozoic sedimentary rocks ranging from Middle Cambrian to Late Devonian, approximately 513 to 359 Ma (fig. 1). Butts and Edmundson (1966) previously mapped Frederick County, Va., at a scale of 1:62,500. Detailed stratigraphic descriptions are included in that report, but revisions to stratigraphic nomenclature of certain units such as the lower Silurian Rose Hill Formation and Keefer Sandstone (formerly Clinton Formation), the Lower Devonian New Creek and Corriganville Limestones of the Helderberg Group (formerly Coeymans and New Scotland Limestones, respectively), the Lower to Middle Devonian Needmore Shale (formerly Onondaga Formation), the Middle Devonian Mahantango Formation (formerly Hamilton Formation), and the Upper Devonian Foreknobs Formation (formerly Chemung Formation) have been made since publication of the report by Butts and Edmundson (1966) and are presented herein (see "Description of Map Units" section). The clastic and carbonate sedimentary strata in the quadrangle reflect nearshore and offshore marine and deltaic depositional environments. The

deposits indicate minor sea level transgression and regression cycles along

a passive continental margin during the Late Cambrian to Middle Ordovician,

and major sea level changes resulting from tectonic uplift during the Late

can be traced between Flint Ridge and the southeast flank of Great North

Mountain. Lower ridges west of Little North Mountain are underlain by

sandstones in the Mahantango (Dm) and Foreknobs (Df) Formations. East of

Little North Mountain, more subtle ridges are held up by limestone and shaly

dolomite of the Elbrook Formation (€e) and thin sandstone beds within the

flow, and terrace deposits that are assumed to be of Quaternary age. Alluvium

(Qa) was mapped along the larger streams; locally, some low alluvial terraces

exist but have not been broken out within this unit. Debris flow deposits (Qdf)

were mapped where recognized in the lidar-derived topographic imagery on the

flanks of Great North Mountain. Colluvium (not mapped separately) covers

most of the steeper slopes and fills the bottoms of many of the mountain

hollows, and is composed mainly of sandstone boulders and cobbles, and

Deformation of the bedrock in the Hayfield quadrangle took place primarily

during the late Paleozoic Alleghanian orogeny when the North American

continent collided with the continents of Africa and Europe, forming the

supercontinent Pangea. Compressive forces caused by the continental collision

resulted in folding and faulting of the sedimentary rock strata, with

northwestward tectonic transport. The breakup of Pangea occurred during the

Mesozoic Era owing to continental rifting; however, deformation from this time

Edmundson, 1966) and includes portions of several other regional folds such as the

Mount Pleasant syncline, the Tavenner Ridge anticline, the Hayfield

Ridge syncline, the Tunnel Ridge syncline, and the Sand Ridge anticline. Most

folds verge to the northwest, reflecting the tectonic transport direction, and trend

approximately 28° to 30° to the northeast 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 with more

steeply dipping beds on the southeastern limb. This is a regional syncline that

quadrangle, forms the western border of the Shenandoah Valley in northern

Virginia and is a series of northeast-trending thrust faults with multiple splays that

separate the Silurian and Devonian shales, siltstones, and sandstones from the

Cambrian and Ordovician carbonate rocks and shales (fig. 1). In the Hayfield

quadrangle, a horse of Middle Ordovician New Market Limestone was raised

between two of the thrust splays in the exposure of the fault zone furthest to

the southwest. The North Mountain fault zone extends to the northwest side of

Little North Mountain and brings Silurian and Lower Devonian rocks onto

Middle Devonian shales of the Marcellus and Needmore Shales.

Interpretation of the fault structure in cross section B-B' followed that of

Orndorff (2012). Irregular outcrops of the Tuscarora Sandstone within the North

Mountain fault zone resulted from cross-strike faulting rather than from thinning

joints measured in the quadrangle is shown in figure 2, which illustrates general

extension in a northeast-southwest direction in response to the regional

thrust transport direction to the northwest. However, the overall distribution of

joints is less regular, as seen in the rose diagram of joint plane azimuths shown

in figure 3. The mean vector of the rose diagram highlights the regional

transport direction to the northwest, but joints also trend northeast-

southwest and north-south, likely as conjugate sets to the primary joint trend.

A lower hemisphere equal-area projection of the poles to planes of all

The North Mountain fault zone, spanning across the southeastern part of the

The quadrangle lies across the Great North Mountain anticlinorium (Butts and

period is not definitively evident in the rocks of the Hayfield quadrangle.

spans all of Frederick County (Butts and Edmundson, 1966).

of sedimentary strata (Giles, 1942).

Surficial materials include unconsolidated alluvium, colluvium, debris

Conococheague Limestone (O€c).

fragments of chert.

Ordovician Taconian orogeny and the Middle to Late Devonian Acadian orogeny. Depositional environments include (from oldest to youngest) (1) a broad, shallow epeiric marine platform represented by the carbonate rocks of Middle Cambrian to Middle Ordovician age; (2) Late Ordovician marine shelf, ramp, and basin deposits of shale and turbiditic flysch; (3) Late Ordovician, Silurian, and Early Devonian nearshore marine sandstones, limestones, and shales; and (4) Early to Late Devonian marine basin, nearshore marine, and fluvial-deltaic siliciclastic shales, siltstones, and minor sandstones. These strata account for about 20,000 feet (ft) of section. Topographic ridges in the quadrangle are primarily held up by sandstones and orthoquartzites that are relatively resistant to erosion. Great North Mountain and Little North Mountain are held up by the Tuscarora Sandstone (Stu), with lesser ridges on the flanks held up by the Keefer Sandstone (Sk). Chert-bearing carbonate units of the Helderberg Group (Dhl) as well as the Oriskany Sandstone (Do) hold up Flint Ridge. The informal Tavenner sandstone (Butts and Edmundson, 1966) of the Wills Creek Formation (Sw) forms a low ridge that

On New Market Limestone (Middle Ordovician) (Cooper and Cooper, **1946**)—Limestone, medium-gray (N 5), light gray-weathering, thick-bedded, micritic, fenestral. Lower 3 ft (1 m) is medium-gray (N 5), thin-bedded, dolomitic limestone and light-gray (N 7)calcareous dolostone. Exposed only in a faulted horse block southeast of Little North Mountain in the southwest corner of the quadrangle. Estimated to be between 80 and 200 ft (24 to 60 m)

> Cambrian) (Stose, 1908)—Interbedded cyclical limestone, dolostone, and sandstone. Limestone, medium-gray (N 5), finegrained, thin- to medium-bedded; includes intraformational conglomerate, algal bioherms, intertidal limestone and dolomitic stringers ("ribbon rock"), and oolite. Dolostone and dololaminite, light-gray (N 7), fine-grained, medium-bedded. Sandstone, lightgray (N 7) to tan, reddish-weathering, medium- to coarse-grained, calcareous. The lower 200 ft (60 m) consist of the Big Spring Station Member (not mapped separately) of Wilson (1952), which consists of gray to tan, reddish-weathering, coarse-grained, calcareous sandstone; medium-gray (N 5), fine-grained limestone with intraformational conglomerate; and light-gray (N 7), finegrained dolostone. Sandstone beds occur at the base of the formation and in two ridge-forming packages in the upper part of the formation. Thickness ranges from 2,200 to 2,600 ft (690 to 810 m),

Elbrook Formation (Middle and Lower Cambrian) (Stose, 1906)—Interbedded limestone, dolostone, and shale. Limestone, medium-gray (N 5), fine- to medium-grained, thin- to mediumbedded; contains algal bioherms, intraformational conglomerates, and mottled beds. Dolostone, light- to medium-gray (N 7 to N 5), yellowish-weathering, fine-grained, medium-bedded. Shale, gray, yellowish-weathering, dolomitic. Lower part of formation is cut out by the North Mountain fault zone. At least 2,300 ft (720 m)

[Showing trace of axial surface, direction of dip of limbs, and direction of plunge

Small—Less than or equal to 10,764 square feet (1,000 square meters)

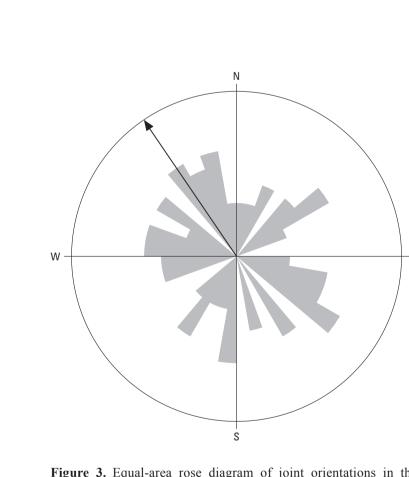


Figure 2. Lower hemisphere equal-area stereographic projection of

poles to planes of joints (n=64) in the Hayfield quadrangle with

Kamb contours at a contour interval of 2 sigma.

Figure 3. Equal-area rose diagram of joint orientations in the Hayfield quadrangle. Petals represents joint azimuths (n=64) binned in 10° increments, dip to right of azimuth. Arrow indicates mean vector of 325.8°±113.8°.

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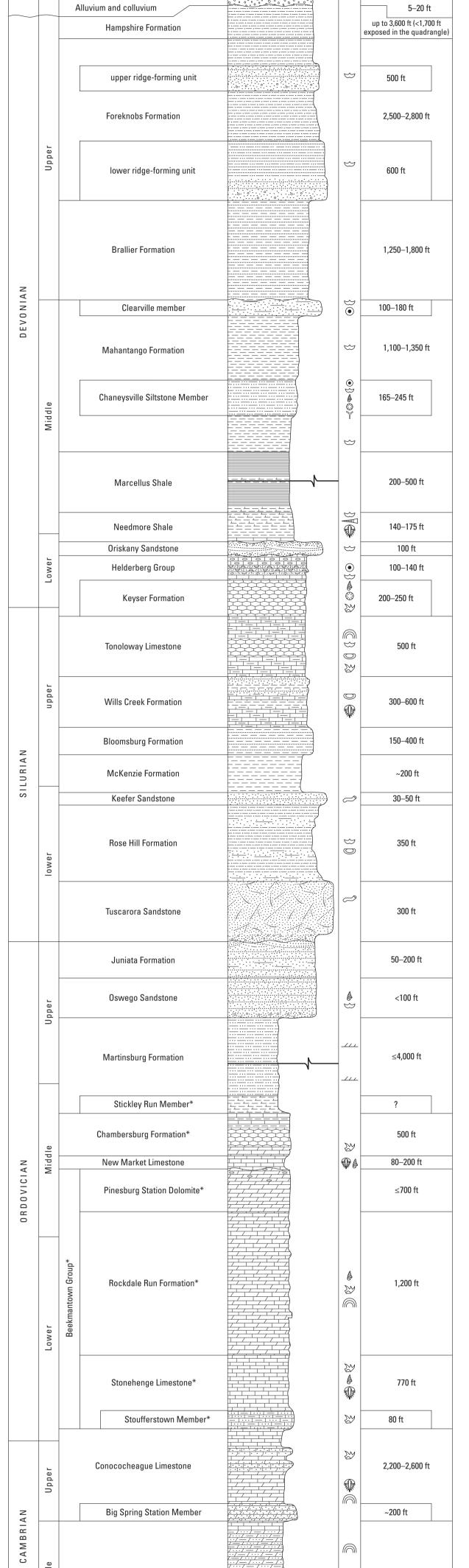
FORMATION AND MEMBER

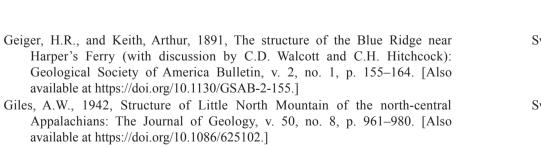
**APPROXIMATE** 

THICKNESS, IN FEET

(Not to scale)

1 foot (ft)=0.3048 meter





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**Elbrook Formation** 

\*not exposed in quadrangle

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**← ♦** Doubly plunging anticline

**▶** ★ Doubly plunging syncline

shales, siltstones, and minor sandstones are also shown. Shaded relief from U.S. Geological Survey National Map.

Figure 1. General geologic map of the Great Valley province in northern Virginia showing the location of the Hayfield 7.5-minute quadrangle, and inset map of the Hayfield

quadrangle showing shaded relief and selected structural elements. Lithotectonic units on inset map: Silurian through Devonian rocks of the Valley and Ridge province and

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