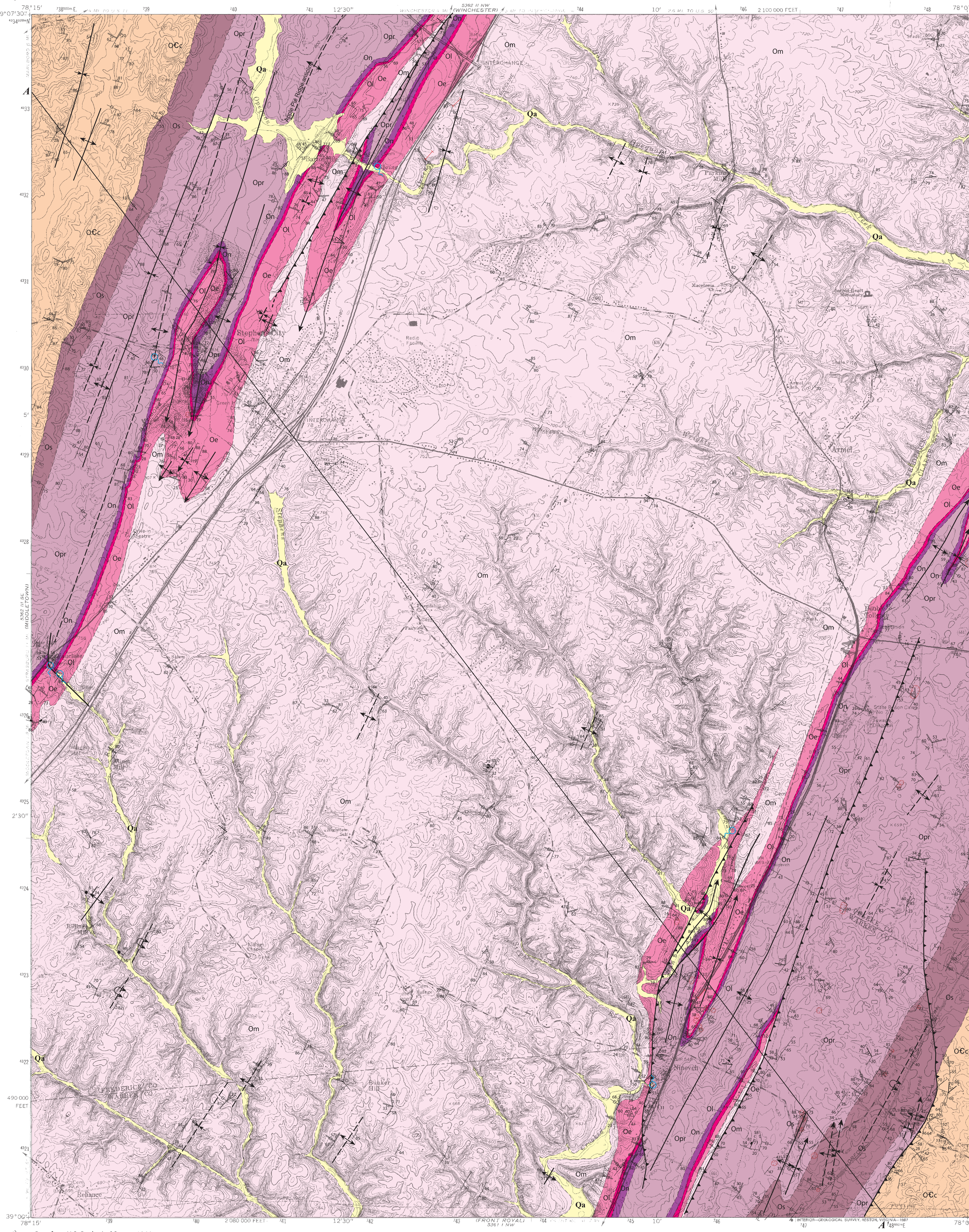
U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY



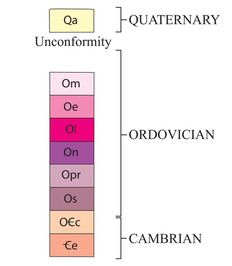
Base from U.S. Geological Survey, 1966
Photorevised 1986
Originally polyconic projection. 10,000 ft grid ticks based on Virginia coordinate system, north zone
10000-meter Universal Transverse Mercator grid ticks, zone 17, shown in blue
1927 North American datum
To place the predicted North American datum 1983 move the projection lines 8 meters south and 23 meters west as shown by dashed corner ticks

These data and base map have been reprojected to Universal Transverse Mercator, zone 17, using the 1983 North American datum

SCALE 1:24 000

Geology mapped 2003-2005

## CORRELATION OF MAP UNITS




## EXPLANATION OF MAP SYMBOLS

Contact--dashed where approximately located; dotted where concealed

Faults

Thrust fault -- saw teeth on upper plate

Strike - slip fault -- arrows indicate sense of motion

Strike and dip of beds

Inclined

Vertical

Overturned

Strike and dip of joints -- point of observation at intersection of multiple symbols; c indicates solutional widening, c indicates calcite fill.

Throughgoing, inclined

Widely spaced ( < 6 ft )

Moderately spaced ( 2 - 6 ft )

Non-throughgoing, vertical

Widely spaced ( > 6 ft )

Moderately spaced ( 2 - 6 ft )

Closely spaced ( > 2 ft )

Non-throughgoing, inclined

Widely spaced ( > 6 ft )

Moderately spaced ( 2 - 6 ft )

Closely spaced ( > 2 ft )

Strike and dip of cleavage

Inclined

Vertical

Folds -- showing trace of axial surface and direction of plunge; dashed where approximately located

Syncline

Anticline

Overturned Anticline

**Spring**

**Sinkhole**

## DESCRIPTION OF MAP UNITS

**Qa** **Alluvium (Holocene and Pleistocene?)** -- Clay, silt, and lesser sand with angular to subrounded clasts, up to boulder size, derived from local bedrock. 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 20 ft

**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, grayish-orange- and dark-yellowish-orange-weathering, commonly silty, generally noncalcareous, although calcareous intervals occur in lower part of formation. Sandstone and siltstone (immature, generally lithic graywacke), medium-gray, grayish-orange-weathering, very fine to fine-grained, commonly graded (fining upwards), lenticular, slightly calcareous to noncalcareous. Many small crossbeds. Graywacke is more abundant and more thickly bedded higher in section where it forms conspicuous ribs in creek beds and may comprise 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, although Bouma cycles c-e appear to be most abundant. Contains a few load casts. Regional thickness may be more than 5,000 feet (Epstein and others, 1995). Only lower 3000 ft exposed in Stephens City quadrangle. Lower several hundred feet, Stickley Run Member, includes all rocks above the highest knobby-weathering limestone of the Edinburg Formation (Oe) up to and including all rocks containing platy limestone interbedded with shales just below shales of the middle part of the Martinsburg Formation. Limestone, medium-gray to grayish-black, olive gray-, grayish-orange-, and dark-yellowish-orange-weathering, very fine grained, laminated and very thin to thin-bedded, argillaceous, commonly micrograded. Shale, medium-gray to medium-dark-gray, calcareous. Also includes several thin beds of yellowish-brown metabentonite. Contact with remainder of Martinsburg is transitional where limestone becomes less abundant upwards. Rough measurement of the width of the outcrop belt between an exposure of the base of the Stickley Run Member just northwest of Double Tollgate and the base of the Edinburg Limestone to the east yields a calculated thickness of about 660 ft. A few thin beds of graywacke, siltstone,and very fine-grained sandstone, generally less than 2 in thick, are found near the top. Calcareous shale averages 49 percent carbonate and limestone averages 75 percent. Includes rocks previously called Oranda Formation and several hundred feet of rock previously included within the lower part of the Martinsburg Formation (Epstein and others, 1995). Thickness about 700 ft.

**Oe** **Edinburg Formation (Middle Ordovician)** -- Interbedded limestone and calcareous shale. Limestone, medium- to medium-dark-gray, fine- to medium-grained, thin- to thick-bedded, irregularly bedded, knobby weathering. Calcareous shale, medium-dark- to very dark gray. Characterized by knobby weathering of fine-grained limestone beds interbedded with shale. Contains several thin beds of yellowish-brown metabentonite. Lower contact transitional with Lincolnshire Limestone (Ol) and placed at base of first knobby-weathering, argillaceous limestone; very dark gray, shaly limestone; or calcareous shale. Thickness about 500 ft

**Ol** **Lincolnshire Limestone (Middle Ordovician)** -- Limestone, dark-gray to very dark gray, medium- to coarse-grained, medium-bedded with bedded black chert nodules; and bioclastic limestone, medium-gray, coarse-grained, thin-bedded. Lower contact placed at base of first dark-gray, medium-grained limestone above dove-gray, micritic limestone of the New Market (On). Thickness ranges from 75 to 105 ft

**On** **New Market Limestone (Middle Ordovician)** -- Limestone, medium-gray and dove-gray, light-gray-weathering, thick-bedded, micritic, fenestral. Lower 10 ft is medium- to light-gray, thin-bedded, dolomitic limestone interbedded with light-gray dololaminite. Base placed at top of last medium-gray, thick-bedded dolostone of Pinesburg Station Dolomite (Opr) and below dolomitic limestone of the New Market. Thickness ranges from 140 to 200 ft

**Opr** **Pinesburg Station Dolomite and Rockdale Run Formation of the Beekmantown Group, undivided (Middle and Lower Ordovician)** -- Dolomite, dololaminite, and limestone

**Pinesburg Station Dolomite (Middle Ordovician)** -- Dolostone and dololaminite, medium- to light-gray, buff- to light-weathering, fine-grained, medium- to thick-bedded 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 formation. Lower contact placed at base of first light-gray, thick-bedded dolostone overlying dominantly limestone cycles of the Rockdale Run Formation (Or). Thickness ranges from 650 to 875 ft

**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. Limestone beds also contain intraformational conglomerates, algal bioherms, bioclastic zones, and burrow mottling. Lithologies occur as carbonate cycles. Gray chert nodules common and occur as nodules as much as 6 in. in diameter and as large masses as much as several feet in diameter; large masses of *Cryptozoon* chert litter soil in lower part of formation and form topographic knolls with little bedrock exposure. Gastropod Lecanospira is common in lower and middle parts of formation. Lower contact placed at base of first crystalline dolostone or dololaminite bed overlying dark-gray, thick-bedded limestone of the Stonehenge Limestone (Os). Thickness approximately 1,500 ft

**Os** **Stonehenge Limestone (Lower Ordovician)** -- Limestone, dark-gray, fine- to medium-grained, thick-bedded, fossiliferous, with crinkly laminations and minor black chert. Also contains algal bioherms, intraformational conglomerates, bioclastic beds, and minor dolostone beds. Contact with underlying Conococheague Limestone (O€c) is gradational; base placed at first dark-gray limestone with crinkly siliceous laminations and above dolostone that caps Conococheague carbonate cycles. Thickness ranges from 600 to 650 ft

**O€c** **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, 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, reddish-weathering, coarse-grained, calcareous sandstone; medium-gray, fine-grained limestone with intraformational conglomerate, and light-gray, fine-grained dolostone. Sandstone beds also occur in upper part of formation and form ridges. Base placed below first calcareous sandstone bed of Big Spring Station Member. Thickness ranges from 2,200 to about 2,600 ft

**€e** **Elbrook Formation (Upper and Middle Cambrian) (In cross section only)** -- 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 dolomite mottling. Generally, lowest beds exposed are bluish-gray,medium- to thick-bedded limestone with dolomite mottles and medium-gray, thick-bedded dolostone. Middle part of formation contains cycles of bluish-gray limestone, light-gray dolostone, and argillaceous dolostone. Cycles of bluish-gray, algal limestone and grainstone and light-gray dolostone similar to the overlying Conococheague Limestone 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 2,300 ft

## DISCUSSION

### INTRODUCTION

The Stephens City quadrangle is located in the Valley and Ridge Province, in the Shenandoah Valley in Frederick, Clarke, and Warren, Counties, Virginia. Approximately 6000 ft of Upper Cambrian to Upper Ordovician sedimentary rocks are exposed and are overlain by Pleistocene (?) and Holocene surficial deposits (map unit Qa). The map area is divided into three geologic regions (fig. 1): (1) Cambrian and Ordovician carbonate rocks of the northwestern side of the Shenandoah Valley; (2) shale, graywacke, and limestone of the Ordovician Martinsburg Formation of the central Shenandoah Valley and Massanutten synclinorium; and (3) Cambrian and Ordovician carbonate rocks of the southeastern side of the Shenandoah Valley. Rocks of all three regions were folded and thrust faulted during the late Paleozoic Alleghanian orogeny. The terrain of the Shenandoah Valley generally is gently to moderately rolling with low relief. Elevations in the Stephens City quadrangle range from about 570 ft in the Opequon Creek valley in the northeastern part of the quadrangle, to 895 ft above sea level in the northwestern corner of the quadrangle. Sinkholes are common in the carbonate rocks of the Shenandoah Valley. Sinkhole and other karst related features for the Stephens City area have been published by Orndorff and Goggin (1994) at a scale of 1:100,000 and Hubbard (1983) at a scale of 1:250,000. Sinkholes and springs encountered during field work for this study are included on the map and in the GIS (Geographic Information System) database. As only a fraction of the ground surface was observed in the map area, these features represent a subset of the total karst morphologies present within the Stephens City quadrangle.

Butts and Edmundson (1966) mapped Frederick County at a scale of 1:62,500. Hubbard (1990) mapped Clarke County at a scale of 1:50,000. Rader and others (1996) compiled the geology of the northern Virginia area, including Frederick County, at 1:100,000 scale.

### STRATIGRAPHY AND ENVIRONMENTS OF DEPOSITION

Rocks in the Stephens City quadrangle range from Upper Cambrian to Upper Ordovician in age and consist of a variety of carbonate and clastic lithologies. Rocks from the Upper and Middle Cambrian Elbrook Formation through the Middle Ordovician Edinburg Formation are dominated by limestone and dolostone, whereas rocks from the Middle and Upper Ordovician Martinsburg Formation comprise shale, siltstone, sandstone, and minor limestone. These rocks, along with fossil content, record the environments of depostion, evolution of sedimentary basins, and tectonic history of the Paleozoic Era of this region.

The Upper Cambrian to Lower Ordovician Conococheague Limestone is the oldest rock unit exposed in the Stephens City quadrangle. The Conococheague crops out in the southeastern and northwestern corners of the map area. The Conococheague comprises repetitive limestone and dolostone beds representing shallowing-upward subtidal, peritidal, and supratidal cycles in restricted shallow marine environments. Cycles generally include, from the base upwards, intraformational conglomerate, grainstone, calcareous siltstone, algal bioherm, ribbon rock (interlaminated tan dolosone and gray limestone), and mudcracked dolostone. Sandstone or dololaminite cap these cycles. Orndorff (1988) indicated that the Cambrian-Ordovician boundary lies within the upper part of the Conococheague in northern Virginia on the basis of conodont biostratigraphy. Recent international agreement on redefinition of the boundary (Cooper and others, 2001), has moved it higher in the formation, probably to within a few tens of feet of the contact with the overlying Stonehenge Limestone.

The Beekmantown Group is divided into a lower limestone unit, the Stonehenge Limestone (Os); a cyclic carbonate unit of limestone and dolostone, the Rockdale Run Formation; and an upper dolostone unit the Pinesburg Station Dolomite. In this study the Rockdale Run Formation and Pinesburg Station Dolomite are combined into one map unit (Opr). The peritidal cycles of the underlying Conococheague Limestone grade upwards to the predominantly subtidal cycles of the Lower Ordovician Stonehenge Limestone with concomitant loss of the dolostone and sandstone lithologies. Channeled algal bioherms and siliceous laminated limestone are characteristic of the Stonehenge Limestone. Taylor and others (1992) suggested that the Stonehenge represents a third-order trangressive-regressive cycle in which the lowermost and uppermost thin-bedded units were deposited in a lagoon and the main algal body of the formation represents the transgression of an offshore barrier complex.

Overlying the Stonehenge, pertidal cycles reappear in the Lower and Middle Ordovician Rockdale Run Formation. These cycles indicate depostional environments similar to those in the Conococheague Limestone. The location of the Lower-Middle Ordovician boundary is in the upper part of the Rockdale Run in this area based on conodonts studies (Harris and Harris, 1978; Harris and others, 1994).

Interbedded limestone and dolostone of the Rockdale Run Formation sharply give way upward to predominantly dolostone of the Middle Ordovician Pinesburg Station Dolomite. The dolostone represents a restricted shallow-marine environment that at times was subaerially exposed as indicated by paleokarst features including irregular bedding and collapse breccia. Collapse breccia occurs in irregular beds as much as 5 ft thick with clasts as large as 1 ft in diameter.

Two periods of dolomitization are recognized. Some of the basal limestones of the Rockdale Run cycles contain dolostone clasts that were reworked from the dolostone that caps the top of the underlying cycles. These clasts suggest an early (penecontemporaneous) period of dolomitization (Walker and others, 1989). A late period of dolomitization is suggested by complete dolomitization of the limestone and dolostone cycles reported from areas of the Middletown and the Mountain Falls quadrangles adjacent to the west and southwest of the Stephens City quadrangle (McDowell, 1995; Orndorff and others, 1999).

Generally the New Market Limestone unconformably overlies the Pinesburg Station Dolomite. Locally, the contact may be conformable where the lower 10 ft is a transition of interval of interbedded dolomitic limestone and dololaminite. The New Market was deposited in a tidal flat or lagoon environment (Walker and others, 1989). Rocks immediately beneath the New Market were deposited on a Cambrian and Ordovician carbonate platform along the passive margin of North America. The New Market represents the change from passive margin to active margin deposition (Rader and Read, 1989) in response to the Taconian orogeny. The remainder of the Middle Ordovician section, from the Lincolnshire Limestone to the Martinsburg Formation, represents the transition from continental shelf to ramp to foreland-basin deposition. The Lincolnshire Limestone (Ol) represents the beginning of the deepening of the Middle Ordovician basin in the central Appalachians. The unit represents a more open marine environment than the New Market, possibly an inner ramp deposit (Walker and others, 1989). Much of the Edinburg Formation (Oe) was deposited in a continental slope environment, probably on a deeper ramp than the Lincolnshire Limestone (Walker and others, 1989). Several metabentonite beds in the Edinburg Formation and overlying Stickley Run Member of the Martinsburg Formation indicate Middle Ordovician volcanism (Walker and others, 1989).

Further deepening of the foreland basin during deposition of the Martinsburg Formation (Om) resulted in an increase in clastic sediments, a gradual loss of carbonate rocks, and the formation of turbidite sequences. The basal Stickley Run Member (Epstein and others, 1995) of the Martinsburg Formation represents the end of Cambrian and Ordovician carbonate deposition. Clastic sediments of the remainder of the Martinsburg were derived from an volcanic island-arc system to the east that filled the basin with shale, siltstone, and graywacke (Walker and others, 1989).

### SURFICIAL GEOLOGY

Surficial deposits in the Stephens City quadrangle consist of alluvium that underlies flood plains along creeks. This unit (Qal) comprises clay, silt, and lesser sand with angular to subrounded gravel, cobbles, and some boulders. Small creeks in the carbonate rocks have generally fine grained alluvium with minor rock clasts. In the Martinsburg Formation outcrop belt, alluvium consists of well to crudely bedded clayey silt with weathered shale fragments.

### SINKHOLES

Sinkholes are closed depressions that result from subsidence due to solution of the bedrock and collapse of the overlying soil into subsurface solution cavities. They are found throughout the areas underlain by Cambrian and Ordovician carbonate rocks. Sinkholes were mapped as they were encountered during fieldwork for this project and represent only a subset of the actual sinkholes present. Orndorff and Goggin (1994) determined that rocks in the interval from the Rockdale Run Formation through the Edinburg Formation had the highest concentrations of sinkholes in the Winchester area.
Most of the sinkholes observed in the Stephens City quadrangle occur in the Cambrian and Ordovician carbonate rocks in the southeastern part of the map area. A high concentration of sinkholes occurs in an area just north-northeast of the village of Nineveh. These are probably associated with enhanced open fracturing near the nose of a syncline and a steep hydraulic gradient towards Crooked Creek just to the west. The relationship between sinkhole development and steep hydraulic gradients has been discussed by previous workers (Hubbard, 1983; White, 1988).

### STRUCTURAL GEOLOGY

Rocks of the Stephens City quadrangle are divided into three lithotectonic units. From southeast to northwest these are, the generally northeast-plunging folded and thrust-faulted rocks of the Cambrian and Ordovician carbonate valley to the southeast of the Martinsburg outcrop belt, the tightly folded and cleaved rocks of the Martinsburg Formation, and the generally southwest-plunging folded and thrust-faulted rocks of the Cambrian and Ordovician carbonate valley to the northwest of the Martinsburg belt. In the transition area between the Martinsburg Formation and the Cambrian and Ordovician carbonate rocks, folds have wavelengths intermediate between the two. The rocks of the Stephens City quadrangle all lie within the Massanutten synclinorium, a regional fold that extends from central Pennsylvania to just south of Staunton, Virginia. The folds and faults in the Stephens City quadrangle resulted from the Late Mississippian to Permian Alleghanian orogeny (Hatcher and others, 1989).

Folds range from overturned and tight upright northwest-verging folds in the Cambrian and Ordovician carbonate rocks southeast of the Martinsburg Formaton; to northeast-trending, tight chevron and curvilinear folds in the Martinsburg Formation; to upright, northwest-verging folds in the Cambrian and Ordovician carbonate rocks northwest of the Martinsburg Formation. Bedding in the Cambrian and Ordovician carbonate rocks and Martinsburg Formation shows a predominantly southeast dip consistent with the west limb of the Massanutten synclinorium and the eastern limbs of upright anticlines and the overturned limbs of other folds. Overturned beds are especially prevalent in the carbonate rocks southeast of the Martinsburg Formation outcrop belt (figs. 2*A*, 2*B*, 2*C*). The regional axial plane strikes of folds is about N. 30° E. as estimated from poles to bedding. The Massanutten synclinorium plunges gently to the southwest in this area and smaller-scale folds superimposed on the western limb of the syclinorium follow this trend. Smaller folds superimposed on the eastern limb, however, plunge gently to the northeast. Examples of the southwest plunging folds include those just west and southwest of the town of Stephens City in the northwestern part of the quadrangle. Examples of the northeast plunging folds can be seen in the folding along the contact between the Stonehenge Limestone and Rockdale Run Formation in the southeastern corner of the quadrangle. Orndorff and others (1999) noted a disharmony in fold wavelength between the Martinsburg Formation and Cambrian and Ordovician carbonate rocks. Cambrian and Lower Ordovician carbonate rocks have folds with longer wavelengths, whereas folds in the Martinsburg have shorter wavelengths. Folds in the Middle Ordovician limestone are intermediate between the two extremes. This disharmonic folding may be due to rheological differences of the rock units.

Most of the faults mapped in the quadrangle are thrust faults associated with synclines and anticlines and have traces trending to north-northeast, sub-parallel to bedding strike. The two easternmost thrust faults in the southeastern corner of the quadrangle are continuations of faults mapped previously in the Front Royal quadrangle, adjacent to the south (Rader and Biggs, 1975). A strike-slip fault is mapped along the contact interval between Middle Ordovician limestone and the Martinsburg Formation at the village of Vaucluse on the central-west edge of the quadrangle. This fault is associated with springs issuing from the carbonates on the north side. These springs should not be confused with Vaucluse Spring, a well-known, large spring located on a different fault about 1 mi. to the west-northwest in the adjacent Middletown quadrangle (Orndorff and others, 1999). This cross-strike fault, like several others mapped in the northern Shenandoah Valley, probably represents strain accommodation during tectonic shortening (Orndorff, 1992).

Joints vary with rock type. The Cambrian and Ordovician carbonate rocks are generally brittle compared to the ductile Martinsburg Formation that contains a well-developed slaty cleavage. The exception is the Stonehenge Limestone which contains well-developed cleavage, especially in the lower part. Data for the joint sets are weighted by counting closely spaced joint sets three times, medium spaced sets two times, and widely spaced sets once. This system approximates the relative importance of each set relative to the volume of the rocks. The carbonate rocks and Martinsburg Formation exhibit a range of cross-strike joints that trend about N. 90° W. to N. 40° W. and a range of longitudinal joints that trend N. 25° E. to N. 40° E. (fig. 3*A*). Intersections of joint and bedding fractures may be important avenues for ground-water movement, particularly across the strike of the rocks. Lineations formed by the intersection of bedding and cleavage planes for Ordovician carbonate rocks northwest of the Martinsburg Formation occur in two populations. One set, produced by the transverse joints, is nearly parallel to bedding with bearings ranging from about N. 20° E. to N. 45° E. and has shallow plunges to either the northeast or southwest. The other set, produced by the cross-strike joints, has bearings trending predominantly to the southeast and plunges that are steeply dipping to near vertical (fig. 3*B*). Lineations formed by the intersection of bedding and cleavage planes for the Martinsburg Formation also occur in two populations. One set, produced by the transverse joints, is nearly parallel to bedding with bearings ranging from about N. 20° E. to N. 50° E. and has shallow plunges to either the northeast or southwest. The other set, produced by the cross-strike joints, has bearings trending predominantly to the southeast and plunges that are moderately dipping to near vertical (fig. 3*C*). Lineations formed by the intersection of bedding and cleavage planes for Ordovician carbonate rocks southeast of the Martinsburg Formation occur in less defined populations. The set produced by the transverse joints has bearings ranging from about N. 10° W. to N. 50° E. and has shallow to moderate plunges to either the northeast or southwest. The other set, produced by the cross-strike joints, has bearings trending to the southeast and the northwest and a range of plunges in either direction (fig. 3*D*). Cleavage in the Martinsburg forms convergent fans and trends in a range of about N. 10° N. to 40° E. or parallels fold trends in the area (Epstein, 1993) (fig 3*E*).

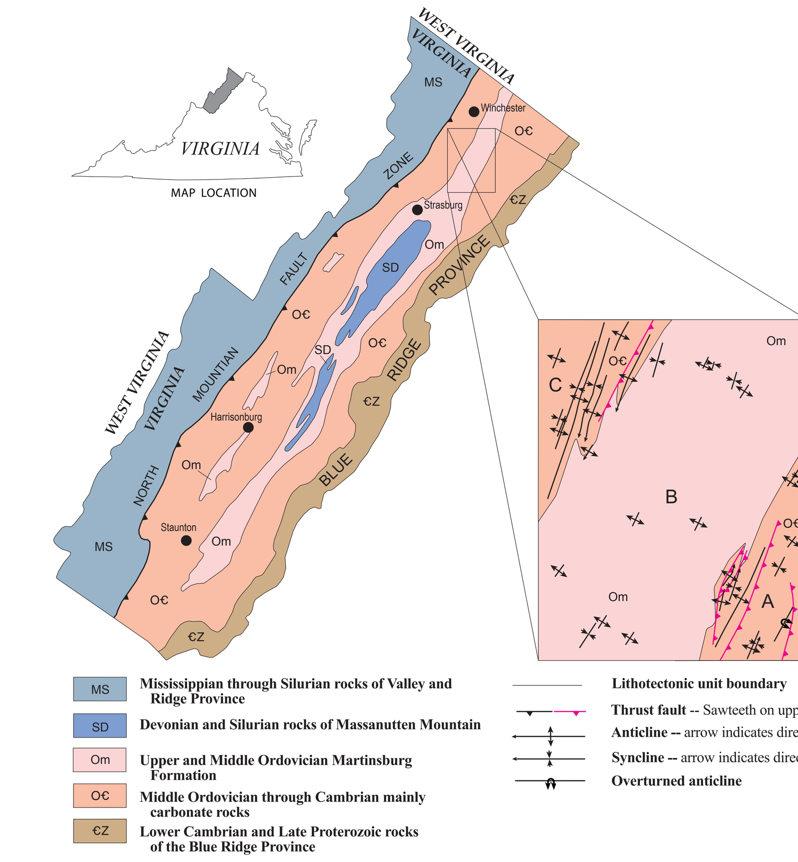



*Figure 1.* -- Regional geologic map of the Shenandoah Valley in northern Virginia showing the location of the Stephens City 7.5-minute quadrangle, and inset map of the Stephens City quadrangle showing structural elements. Lithotectonic units on inset map: A, Cambrian and Ordovician carbonate rocks on the southeastern side of the Massanutten synclinorium; B, Martinsburg Formation; C, Cambrian and Ordovician carbonate valley on the northwestern side of the Massanutten synclinorium.

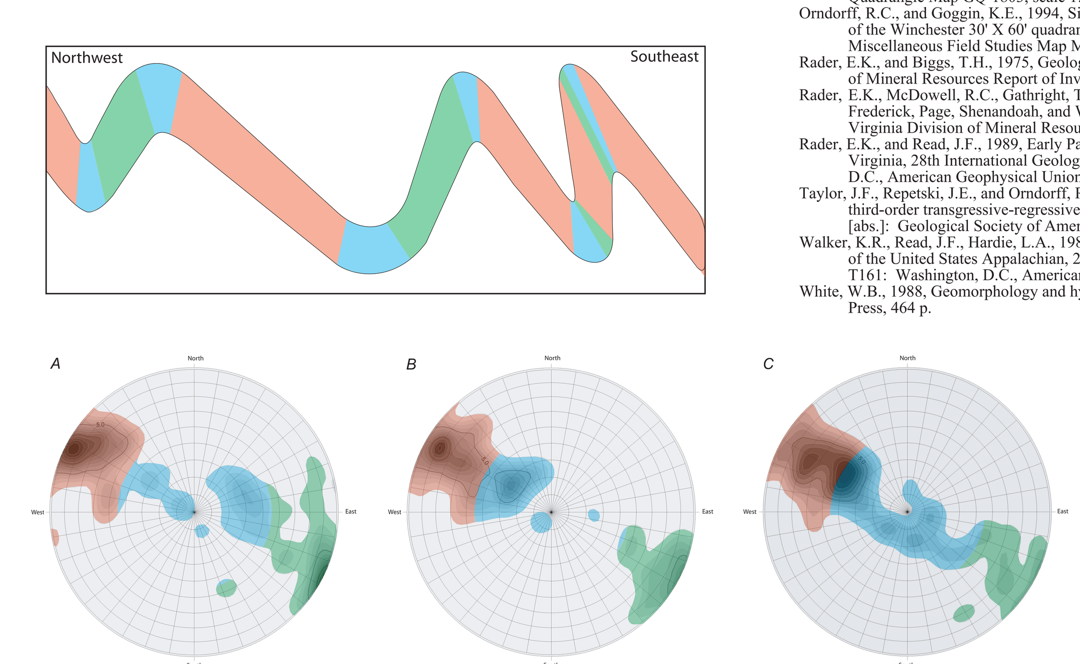



*Figure 2.* -- Lower hemisphere equal-area stereographic projections of structural data from the Stephens City quadrangle and generalized conceptual cross-section illustrating areas of overturned and upright folds represented by the distribution of the bedding data. Green color indicates bedding dipping steeply to the northwest, blue color indicates beds with shallow to moderate dips, and orange color indicates beds dipping steeply to the southeast. *A*, Poles to bedding of Cambrian and Ordovician rocks to the northwest of the Martinsburg Formation. *B*, Poles to bedding of the Martinsburg Formation. *C*, Poles to bedding of Cambrian and Ordovician carbonate rocks southeast of the Martinsburg Formation.

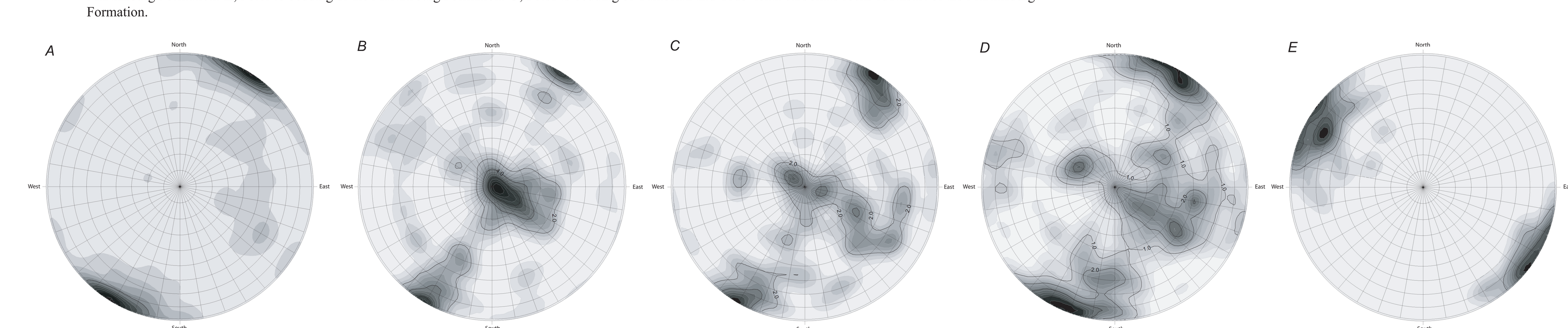
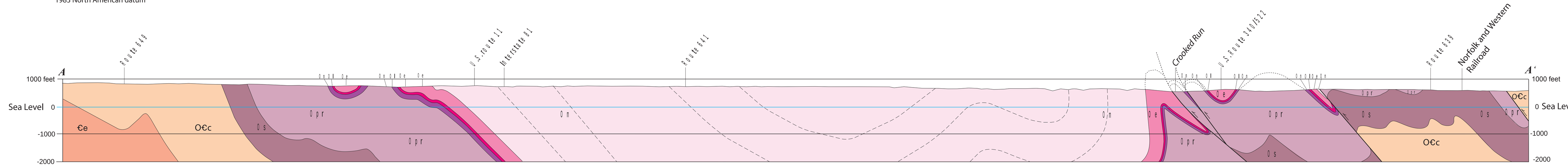



*Figure 3.* -- Lower hemisphere equal-area stereographic projections of structural data from the Stephens City quadrangle. *A*, Poles to joints for entire map area. *B*, Lineation of intersection of bedding and cleavage of Cambrian and Ordovician rocks to the northwest of the Martinsburg Formation. *C*, Lineation of intersection of bedding and cleavage of the Martinsburg Formation. *D*, Lineation of intersection of bedding and cleavage of Cambrian and Ordovician rocks to the southeast of the Martinsburg Formation. *E*, Poles to cleavage in the Martinsburg Formation.

## REFERENCES CITED

Butts, Charles, and Edmundson, R.S., 1966, Geology and mineral resources of Frederick County: Virginia Division of Mineral Resources Bulletin 80, 142 p.
Cooper, R.A., Nowlan, G.S., and Williams, S.H., 2001, Global stratotype section and point for base of the Ordovician System: Episodes, v. 24, p. 19–31.
Epstein, J.B., 1993, Structural analysis of divergent folds in the Martinsburg and Oranda Formations Middletown 7.5-minute quadrangle, Virginia: U.S. Geological Survey Open-File Report 93-25, 13 p.
Epstein, J.B., Orndorff, R.C., and Rader, E.K., 1995, Middle Ordovician Stickley Run Member (new name) of the Martinsburg Formation, Shenandoah Valley, northern Virginia, in Stratigraphic notes, 1994: U.S. Geological Survey Bulletin 2135, p. 1-13.
Harris, A. G. and Harris, L.D., 1978, Lower-Middle Ordovician boundary in south-central Appalachian basin--conformity and unconformity—the Beekmantown Group "updated," *in* Geological Survey Research, 1977: U.S. Geological Survey professional Paper 1100, p. 231.
Harris, A.G., Stamm, N.R., Weary, D.J., Repetski, J.E., Stamm, R.G., and Parker, R.A., 1994, Conodont color alteration index (CAI) map and conodont-based age determination for the Winchester 30' X 60' quadrangle and adjacent areas, Virginia, West Virginia, and Maryland: U.S. Geological Survey Miscellaneous Field Studies Map MF-2239, scale 1:100,000.
Hatcher, R.D., Jr., Thomas, W.A., Geiser, P.A., Snoke, A.W., Mosher, Sharon, and Wiltschko, D.V., 1989, Alleghanian orogen, chapter 5 in Hatcher, R.D., Jr., Thomas, W.A., and Viele, G.W., eds., The Appalachian-Ouachita orogen in the United States: Boulder, Colo., Geological Society of America, The Geology of North America, v. F-2, p. 233-318.
Hubbard, D.A., 1983, Selected karst features of the northern Valley and Ridge Province, Virginia: Virginia Division of Mineral Resources Publication 44, scale 1:250,000.
Hubbard, D.A., 1990, Geologic map of Clarke County, Virginia; Map of selected hydrogeologic components for Clarke County: Virginia Division of Mineral Resources Publication 102, 2 sheets, scale 1:50,000.
McDowell, R.C., 1995, Preliminary geologic map of the Mountain Falls quadrangle, Frederick and Shenandoah Counties, Virginia and Hampshire County, West Virginia: U.S. Geological Survey Open-File Report 95-620, scale 1:24,000.
Orndorff, R. C., 1988, Latest Cambrian and earliest Ordovician conodonts from the Conococheague and Stonehenge Limestones of northwestern Virginia: U.S. Geological Survey Bulletin 1837-A, 23 p.
Orndorff, R.C., 1992, Tectonic significance of cross-strike faults in the central Appalachian Great Valley of Maryland and West Virginia: Southeastern Geology, v. 32, no. 4, p. 197-214.
Orndorff, R.C., Epstein, J.B., and McDowell, R.C., 1999, Geologic map of the Middletown quadrangle, Frederick, Shenandoah, and Warren Counties, Virginia: U.S. Geological Survey Geologic Quadrangle Map GQ-1803, scale 1:24,000.
Orndorff, R.C., and Goggin, K.E., 1994, Sinkholes and karst related features of the Shenandoah Valley of the Winchester 30' X 60' quadrangle, Virginia and West Virginia: U.S. Geological Survey Miscellaneous Field Studies Map MF-2262, scale 1:100,000.
Rader, E.K., and Biggs, T.H., 1975, Geology of the Front Royal quadrangle, Virginia: Virginia Division of Mineral Resources Report of Investigations 40, 91 p. scale 1:24,000.
Rader, E.K., McDowell, R.C., Gathright, T.M., II, and Orndorff, R.C., 1996, Geologic map of Clarke, Frederick, Page, Shenandoah, and Warren Counties, Virginia: Lord Fairfax Planning district: Virginia Division of Mineral Resources Publication 143, scale 1:100,000.
Rader, E.K., and Read, J.F., 1989, Early Paleozoic continental shelf to basin transition, northern Virginia, 28th International Geological Conference, Field Trip Guidebook T221: Washington, D.C., American Geophysical Union, 9 p.
Taylor, J.F., Repetski, J.E., and Orndorff, R.C., 1992, the Stonehenge Limestone: Anatomy of a third-order transgressive-regressive cycle in the Lower Ordovician of the central Appalachians [abs.]: Geological Society of America, Abstracts with Programs, v. 24, no. 3, p. 80.
Walker, K.R., Read, J.F., Hardie, L.A., 1989, Cambro-Ordovician carbonate banks and siliclastic basins of the United States Appalachian, 28th International Geological Congress, Field Trip Guidebook T161: Washington, D.C., American Geophysical Union, 88p.
White, W.B., 1988, Geomorphology and hydrology of karst terrains: New York, Oxford University Press, 464 p.




# GEOLOGIC MAP OF THE STEPHENS CITY QUADRANGLE, CLARKE, FREDRICK, AND WARREN COUNTIES, VIRGINIA

By
David J. Weary, Randall C. Orndorff, and Wilma Alemán-González

2006
U.S. Geological Survey Open File Report OF-2006-1173