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A Structural and Stratigraphic Excursion Through the Shenandoah Valley, Virginia

by

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Field trip

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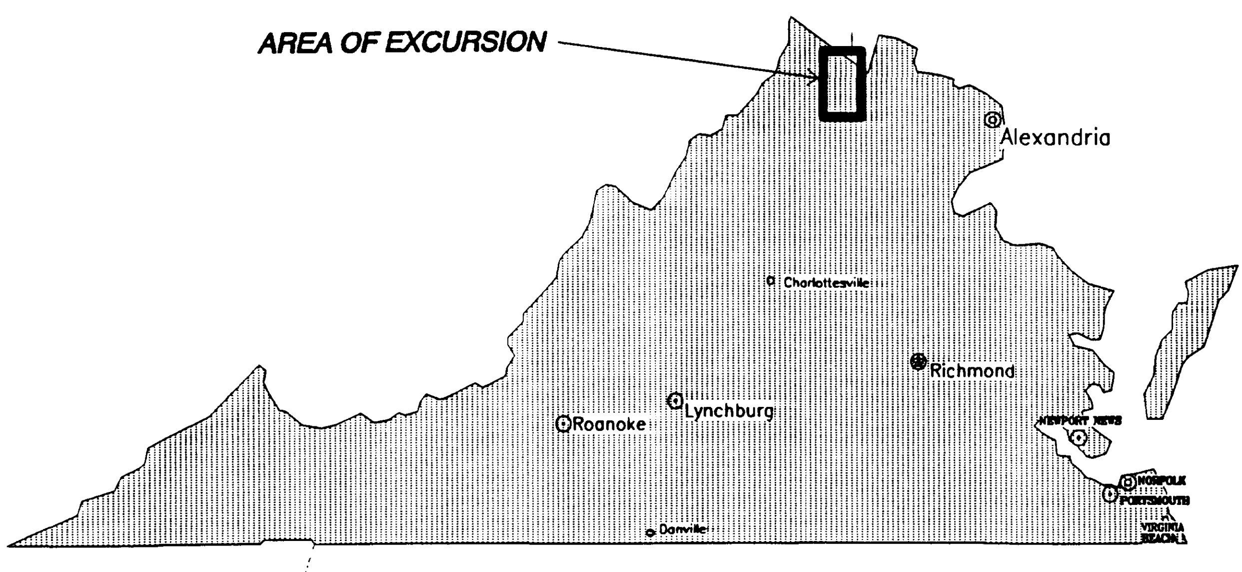


A STRUCTURAL AND STRATIGRAPHIC EXCURSION THROUGH THE SHENANDOAH VALLEY, VIRGINIA

INTRODUCTION

The Shenandoah Valley of northern Virginia is underlain by limestone, dolostone, shale, sandstone, and siltstone of Early Cambrian to Late Ordovician age (about 550 to 450 million years old) (fig. 1). The valley is a part of the Valley and Ridge Physiographic Province and is bounded by the Blue Ridge Province on the southeast, comprising rocks of Precambrian and Cambrian age that are thrust over the younger strata of the Shenandoah Valley, and by mountain ridges of the Valley and Ridge Province to the northwest containing clastic ridge-forming rocks of Silurian and Devonian age. Rocks of the Shenandoah Valley are part of the Massanutten synclinorium, a large complex structure of folds and faults that extends for many miles to the northeast and southwest (fig. 2). The northwestern boundary of the valley is marked by the North Mountain fault zone, a thrust zone that brings Cambrian and Ordovician rocks over Silurian and Devonian rocks.

Cambrian and Lower Ordovician rocks of the Shenandoah Valley were deposited in what initially was a shallow sea on the edge of the North American Continent. During Middle and Late Ordovician time, sediments were deposited in a basin that became progressively deeper. These rocks were subsequently overlain by Silurian and Devonian sediments. During the Alleghanian orogeny, sometime between the Mississippian and Permian Periods, the rocks were folded, faulted, and uplifted as the North American and African plates converged and collided. Processes of erosion acted upon these deformed rocks resulting in the formation of ridges and mountains underlain by resistant rocks such as sandstone and quartzite, and valleys underlain by weaker shale and limestone that are more vulnerable to erosion. Erosional processes, including mass wasting, solution, and fluvial transport continue today.

This field trip will examine many different formations at five locations (fig. 3). A variety of different rock types, including limestone, dolostone, shale, and graywacke, and structures, such as folds and faults, that reveal the geologic history of the Shenandoah Valley will be examined. Interpretations of the paleoenvironments and sedimentary processes prevalent during the Cambrian and Ordovician Periods will be presented at the first three stops. The last two stops will be along the North Mountain fault zone where folds and faults produced during the Alleghanian orogeny will be examined.

ROAD LOG

Miles (cumulative)	Explanation
0.0	Start trip at the intersection of Interstate Highway 81 and State Highway 7, just east of Winchester,

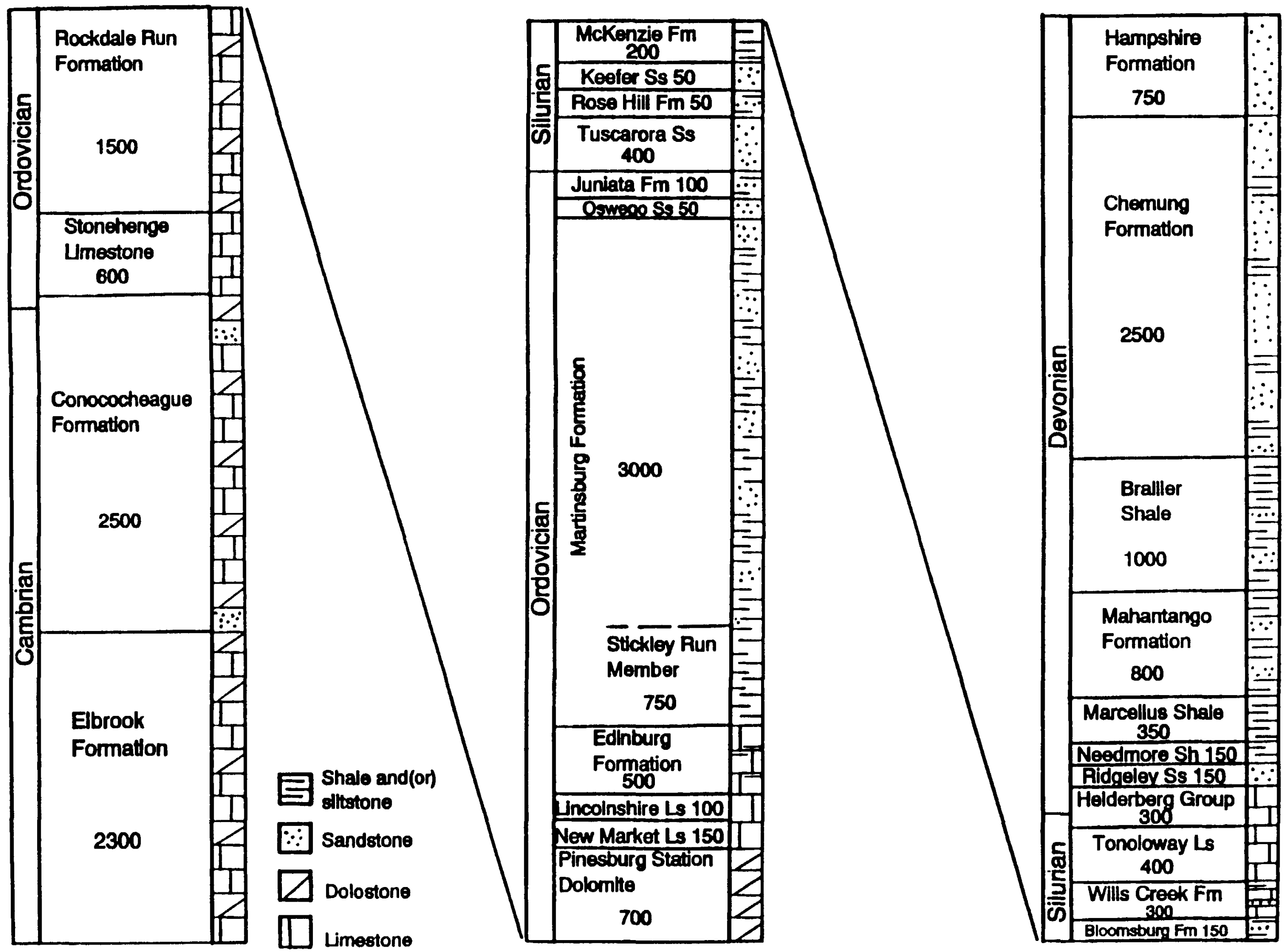


Figure 1. Stratigraphic units of northern VA and eastern WV and their thicknesses (in feet).

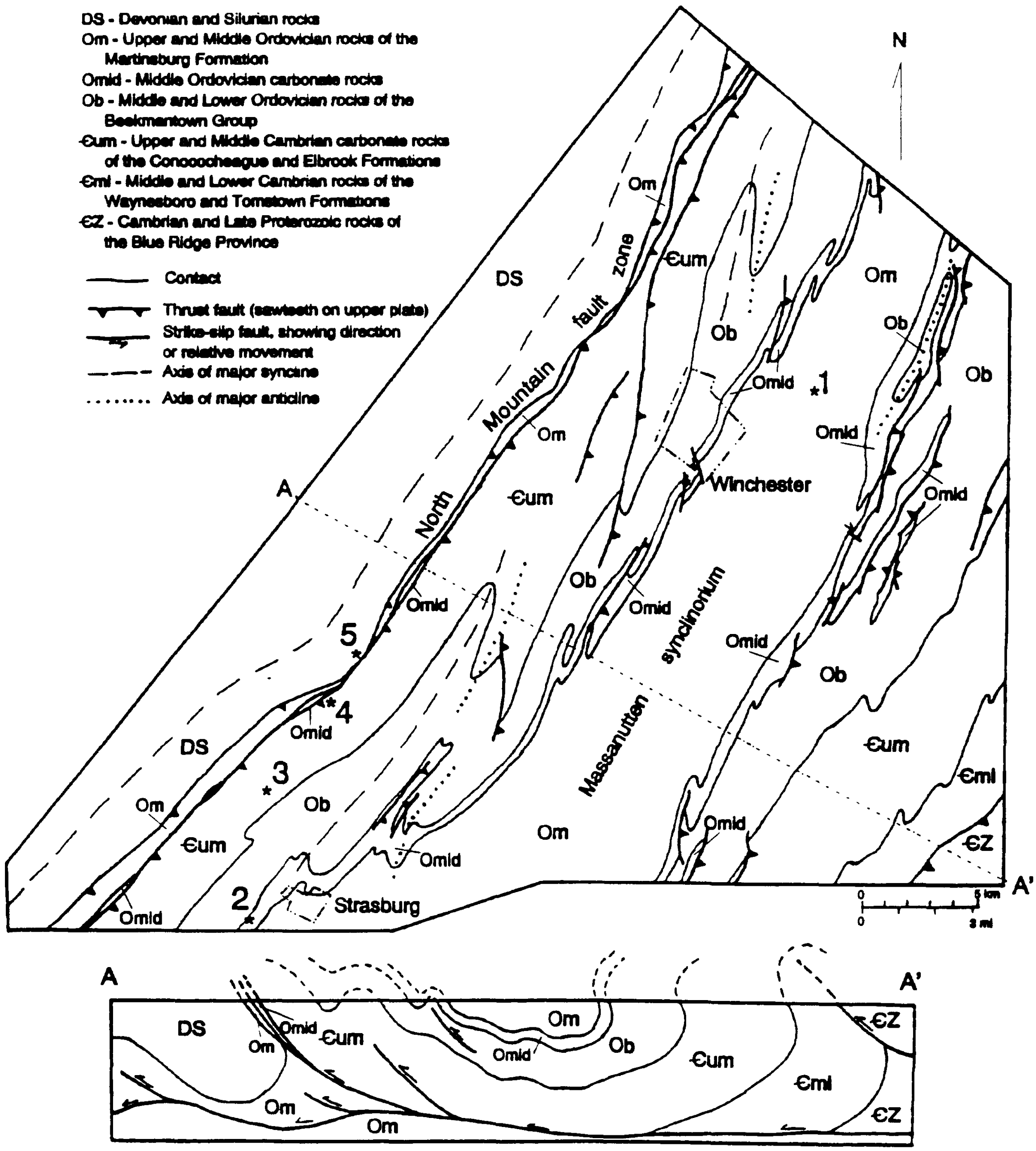


Figure 2. Geologic map and generalized cross section of the Shenandoah Valley of northern Virginia showing locations of field trip stops.

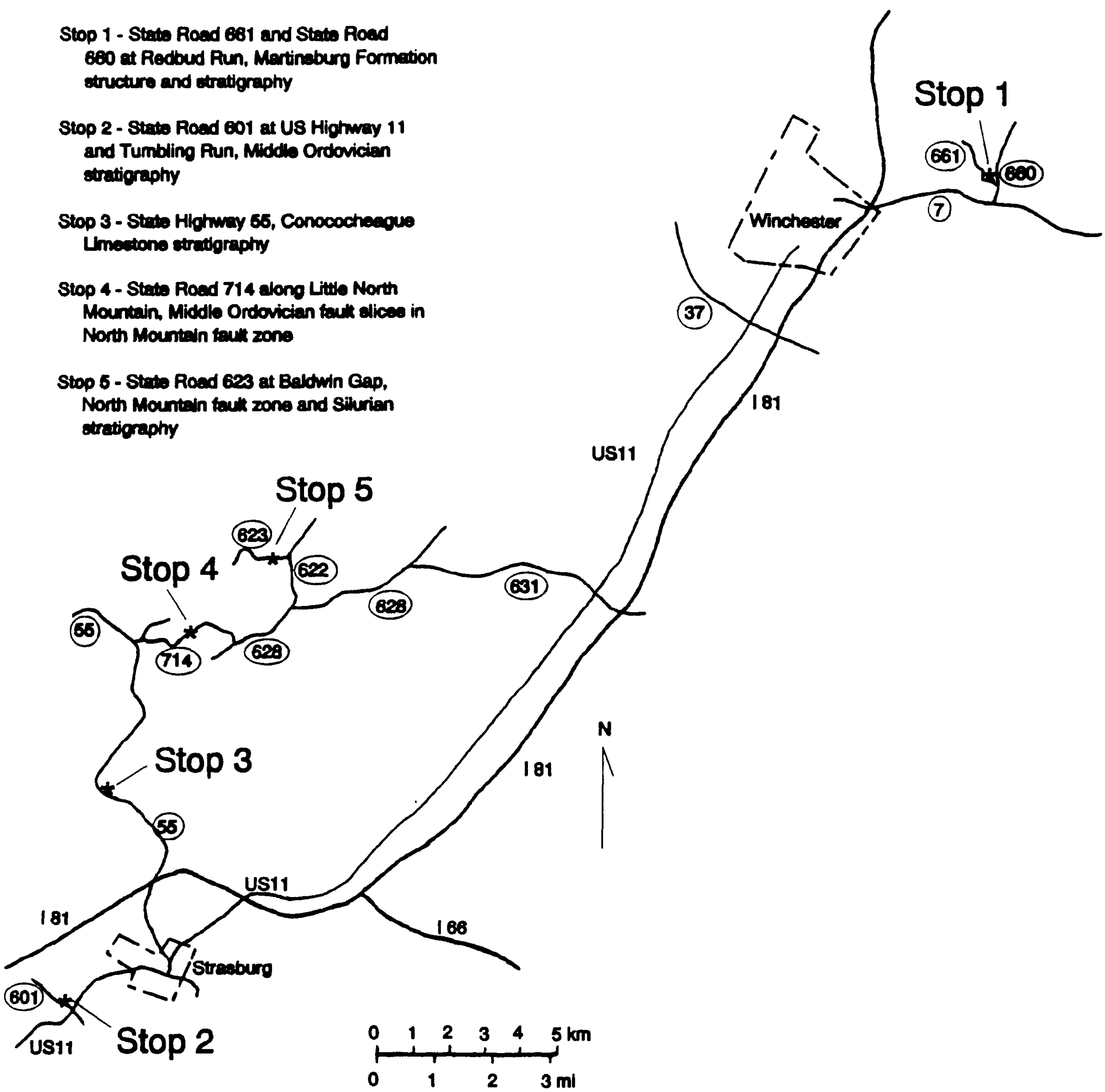


Figure 3. Road map showing field trip stops.

	Frederick County, VA. Road log begins in parking lot of Shoneys Restaurant on southwest corner of interchange. Proceed east on State Highway 7.
2.2	Intersection of State Highway 7 and State Road 660. Turn left on State Road 660.
2.6	Intersection of State Road 660 and State Road 661. Park along side of road at intersection. Proceed on foot to outcrop on north side along State Road 661.

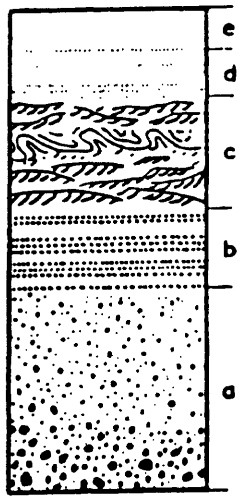
STOP 1. MARTINSBURG FORMATION, STRUCTURE AND STRATIGRAPHY

The Martinsburg Formation of Middle and Late Ordovician age is exposed in this roadcut, exhibiting folds and secondary cleavage typical of structures in the Appalachians. The rock types and their sedimentary structures give insight to the manner in which they were deposited.

The Martinsburg Formation is composed of shale, siltstone, and impure sandstone (graywacke). It is tightly folded in this area and makes up the core of the Massanutten synclinorium (fig. 2). The Martinsburg was deposited in a foreland basin that developed during the Taconic orogeny, a tectonic event in which North America converged with the African continent to the east during the latter half of the Ordovician Period. By comparing the rock types in this unit with sediments deposited in deep basins today, we can determine that the Martinsburg developed in a deep oceanic environment. Rocks in this outcrop contain sedimentary structures typical of turbidite sequences or Bouma cycles (fig. 4). Turbidity flows within the Martinsburg were generated by liquefaction of sandy muds, possibly set into motion by earthquakes. These turbidity flows moved down the gentle slope of the basin, which may have averaged about 2 degrees. Coarser sediments settled first, closer to the source, and finer sediments accumulated further away. Because of sequential deposition of these sediments, a typical Bouma cycle consists of graded beds (sandy beds that become finer grained upward) at the base, overlain by a sequence of parallel-laminated sandy beds, then very fine-grained sand and coarse silt with ripple crossbeds, succeeded by an upper parallel-laminated unit, and finally topped by a pelitic (mudstone) interval (fig. 4). At several places, prominent graded graywacke beds mark the base of the Bouma cycles (fig. 5).

Starting at the west end of the outcrop on the north side of State Road 661 (0 feet on figure 5), beds of the Martinsburg dip to the east in the west limb of a small syncline. Intense weathering at the extreme western end of the outcrop obliterates most of the bedding. At about 250 feet, bedding is well defined and flattens eastward until 275 feet where a small anticline interrupts the pattern. Bedding is readily recognized in this part of the outcrop since cleavage is not well

Turbidite Profile (Bouma Cycle)



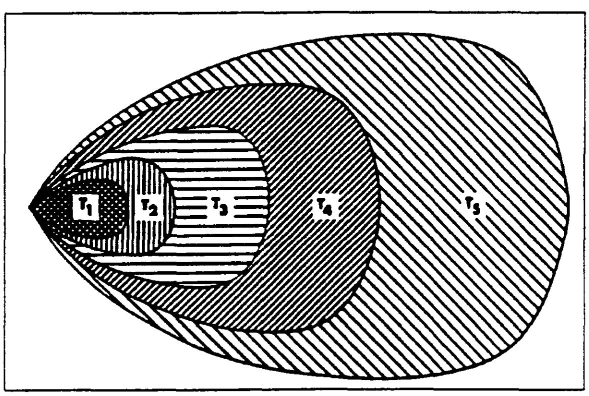
(a) GRADED INTERVAL: a sandy or gravelly interval generally showing more or less distinct graded bedding and no other mesoscopic structures;

(b) LOWER PARALLEL LAMINATION: sand with coarse parallel lamination and graded bedding, the contacts being gradational;

(c) CURRENT RIPPLE LAMINATION: very fine sand to coarse silt with small-scale ripple-cross-stratification and occassional convolute lamination, indistinct grading being present; bottom contact commonly being sharp;

(d) UPPER PARALLEL LAMINATION: sandy to silty clay with indistinct parallel lamination and a distinct lower contact;

(e) PELITIC INTERVAL: mud without visible sedimentary structures.



Hypothetical plan showing geographic distribution of intervals in a flysch profile from T1 at the base to T5 at the top (from Bouma, 1962)

Bouma (1962) noted that the sequences developed as superimposed tongue-shaped bodies, with finer intervals being of larger areal extent. Sequences close to the source would have all intervals represented; those farther away would lack the lower intervals. Removal of the upper intervals by erosion would produce sequences with the top, or top and basal, intervals cut out.

Figure 4. Explanation of Bouma cycles.

GSW TRIP, STOP 1

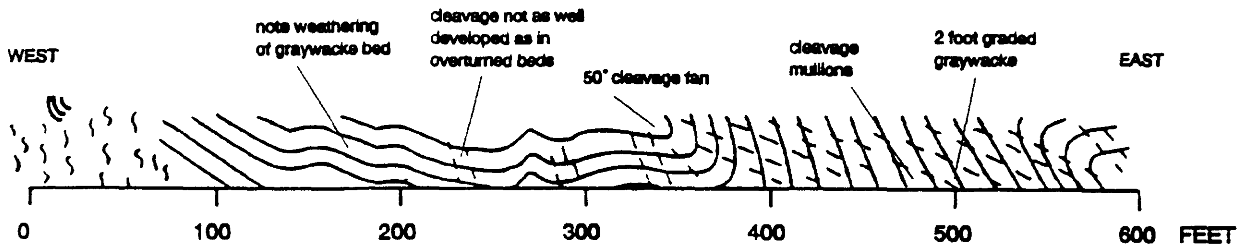


Figure 5. Geologic cross section of the Martinsburg Formation at the junction of State Road 660 and State Road 661, 0.3 mile north of State Highway 7, 4 miles east of Winchester, Stephenson 7.5-minute quadrangle. Solid lines are bedding; dashed lines are cleavage.

developed. Cleavage is the tendency of a rock to split along closely spaced planes dependent on mineral orientation, and has a direct relationship to the fold in which it is found. It is generally parallel to the axial planes of the folds, but diverges to form a "cleavage fan" on the limbs of the folds, as seen at 375 feet and 580 feet.

At 375 feet, the bedding becomes very steep forming the east limb of an overturned fold. The overturned sequence continues to 580 feet where cleavage is prominent, displaying an important interpretive relationship between cleavage and bedding. The beds dip steeply to the east while the cleavage dips more gently in the same direction. This relationship indicates that the rocks are overturned. Thus, if bedding and cleavage dip in the same direction and bedding is steeper than cleavage, then the rocks are overturned. On the other hand, if bedding dips more gently than cleavage in the same direction, then bedding is upright, as it is at 240 feet. Additionally, if bedding and cleavage dip in opposite directions, then bedding is also upright, as it is at 590 feet at the east end of the outcrop, near the intersection with State Road 660.

At 600 feet the beds turn back over to the upright position in the upright east limb of an overturned anticline. The rocks become nearly flat lying and the cleavage fans around the fold and dips more steeply to the southeast. Confirmation of upright or overturned beds can be determined from sedimentary structures such as crossbedding (thin sandy beds that are inclined and curved away from main bedding planes; concave side points to top of bed) and graded bedding (beds that change from coarser-grained sediment near the base to finer-grained sediment near the top) in many parts of the exposure. At about 480 feet, the intersection of the cleavage with sandy and silty beds creates wave-like structures along the bedding called cleavage mullions.

	Turn around and proceed south on State Road 660.
3.0	Intersection of State Road 660 and State Highway 7. Turn right on State Highway 7.
5.1	Interchange of State Highway 7 and Interstate Highway 81. Head south on Interstate Highway 81.
7.4	Interchange of Interstate Highway 81 and U.S. Highway 50. Continue south on Interstate Highway 81.
10.8	Interchange of Interstate Highway 81 and State Highway 37, exit 310, Kernstown. Take exit and follow signs to U.S. Highway 11 south.

11.0	Turn right at stop light at top of exit ramp onto State Highway 37 north.
11.2	Interchange of State Highway 37 and U.S. Highway 11. Take second exit onto U.S. Highway 11 south. Turn right at end of ramp.
14.7	Intersection of U.S. Highway 11 and State Highway 277 at Stephens City. Continue south on U.S. Highway 11.
15.9	Drive-in theater on right, one of the few remaining artifacts of Americana.
18.2	Massanutten Mountains ahead and to the left. This mountain range extends southward for about 40 miles from Strasburg to Harrisonburg, VA. The mountains are held up by the resistant Massanutten Sandstone of Silurian age. Valleys within the range are underlain by rocks as young as Devonian, making up the deepest part of the Massanutten synclinorium.
19.0	Lord Fairfax Community College in Middletown on left.
20.9	Cedar Creek battlefield and Belle Grove mansion on right. This is the site of a major Civil War battle in 1864 in which Confederate troops made an early morning surprise attack on Union encampments. After overrunning the astonished Union troops the Confederate soldiers pillaged the camp site. This allowed the Union troops to reorganize. Later in the day, the Union troops routed the Confederates and pushed them back toward the south. The Shenandoah Valley is rich in Civil War history with many battles fought in the period from 1861 to 1865. The Valley was not only important for its agriculture but also provided easy access north and south for both the Confederate and Union armies.
22.3	Type section of the Stickley Run Member of the Martinsburg Formation (Epstein and others, in

press) on left along north-bound lanes of U.S. Highway 11. This member contains rocks that were previously included in the Oranda Formation and the lowest calcareous shale and shaly limestone of the Martinsburg Formation. The Stickley Run is as much as 900 feet thick in this area, but only the lower 140 feet are exposed along the highway.

22.5 Bridge over Cedar Creek. Cedar Creek flows from west of Little North Mountain to where it enters the Shenandoah River 1.5 miles southeast of this bridge. The creek is incised throughout most of the Shenandoah Valley and provides excellent exposures of the Cambrian Elbrook Formation through the Middle Ordovician Edinburg Formation. It also contains large carp.

23.4 Interchange of U.S. Highway 11 and Interstate Highway 81. Proceed south on U.S. Highway 11 towards Strasburg.

24.7 As you descend the hill you will have a good view of the valley of the North Fork of the Shenandoah River and the Massanutten Mountains on the left and Little North Mountain on the right.

25.3 Intersection of U.S. Highway 11 and State Highway 55 west. Continue south on U.S. Highway 11.

25.5 Intersection of U.S. Highway 11 and State Highway 55 east in downtown Strasburg. Turn right at stop light and continue on U.S. Highway 11 south.

26.4 Floodplain of North Fork of the Shenandoah River on left. The Shenandoah Valley is noted for agriculture; some of the most productive soils are on the floodplain of the Shenandoah River.

26.9 Beds of the Middle Ordovician Edinburg Formation form dip-slope on right side of road.

27.4 Intersection of U.S. Highway 11 and State Road 601. Turn right on State Road 601.

27.7 Pull off along left side of road.

STOP 2. TUMBLING RUN. MIDDLE ORDOVICIAN STRATIGRAPHY AND PALEOENVIRONMENTS

The Middle Ordovician rocks exposed in this roadcut record a major change in the tectonic history of North America (figure 6). Dolostone of the upper part of the Beekmantown Group exposed on the west side of the bridge over Tumbling Run was deposited in a shallow water, restricted marine (tidal flat or lagoon) environment during a time when the east coast of North America was a passive margin (a trailing edge continental plate boundary). An unconformity can be seen between the rocks of the Beekmantown Group and the overlying New Market Limestone several feet above creek level just north of the bridge. This unconformity locates the change from deposition along a passive margin to an active margin (a convergent continental plate boundary). Moving up section to the southeast, we find rocks that were deposited in progressively deeper environments, from tidal flats and shallow subtidal marine (New Market Limestone), to open marine, shallow ramp (Lincolnshire Limestone), to deep ramp and slope (nodular facies in the Edinburg Formation), and to anoxic slope and basin (mudstone facies in the Edinburg Formation) (figure 7). The overlying rocks of the Martinsburg Formation exposed along and southeast of U.S. Highway 11 were deposited in a foreland basin that was positioned between North America and a volcanic arc to the east. Volcanic ash or bentonite beds in the Edinburg Formation and the Stickley Run Member of the Martinsburg Formation are evidence for the volcanic activity. A modern analog to this geologic setting is the sea that exists between mainland Asia and the Indonesian volcanic arc.

Environments of deposition outlined above are deduced from the types of rocks, their sedimentary structures, and their mutual relationships. Comparison of these features with those in modern carbonate banks, such as northern Australia and the Bahamian Platform, helps to determine environments of deposition. Fossils found can also be of significant aid in determining depositional environments. Fossils found in the Tumbling Run exposures include ostracodes, brachiopods, gastropods, cephalopods, sponges, trilobites, bryozoans, and graptolites. Some organisms were restricted to shallow waters while others only lived in deeper waters.

Dolostone of the upper part of the Beekmantown Group is medium to light gray and is partly laminated. The New Market Limestone is a distinct "dove gray" and medium-gray, thick-bedded, very fine-grained limestone, which weathers light-gray. The Lincolnshire Limestone is a dark gray to very dark gray, medium-bedded, medium- and fine-grained limestone that contains thin beds of fossil hash. Distinctive black chert nodules occur throughout the Lincolnshire. The Edinburg

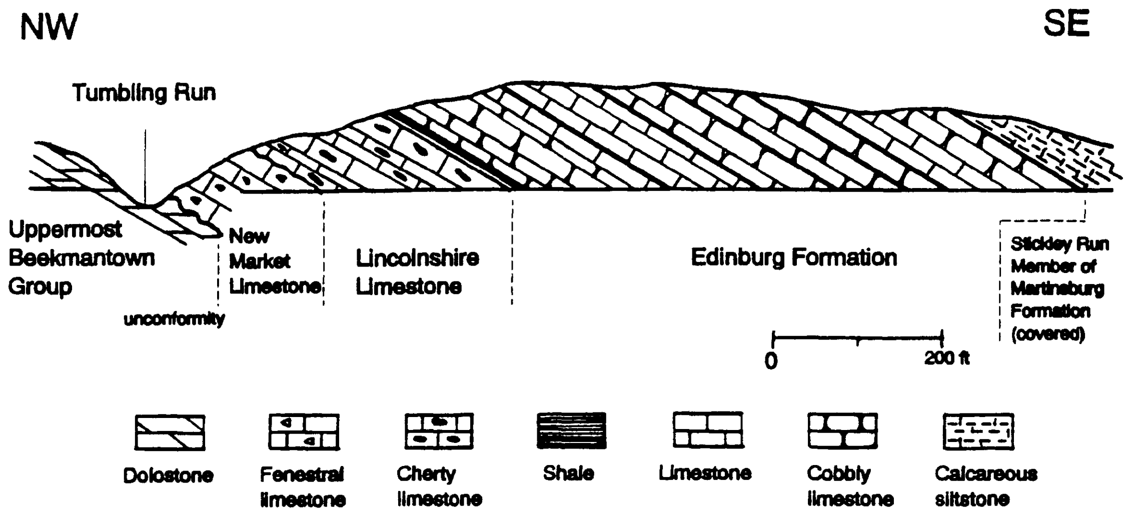


Figure 6. Generalized outcrop sketch (cross section) of Tumbling Run, Middle Ordovician section along State Road 601, just west of US Highway 11 and 1.5 miles southwest of Strasburg, Toms Brook 7.5-minute quadrangle. This section shows the change from passive margin carbonate deposition (Beekmantown Group) to active or convergent margin, foreland basin deposition (New Market Limestone to Martinsburg Formation).

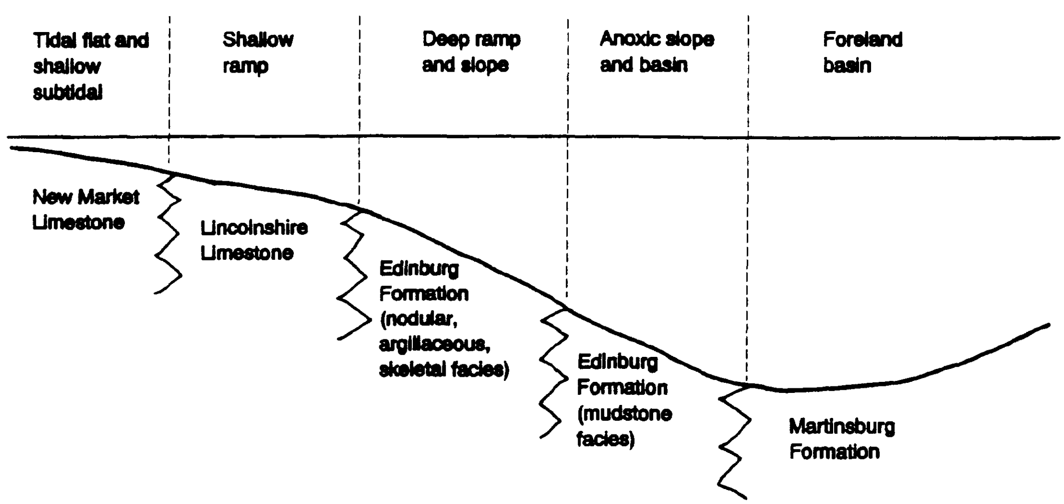


Figure 7. Diagram showing depositional setting of Middle Ordovician formations in a tidal flat to foreland basin transition.

Formation occurs in two facies in the Tumbling Run section: a nodular, thin-bedded, fine-grained, silty limestone interbedded with very dark gray shale, and an evenly thin-bedded, very dark gray mudstone.

	Return to intersection of State Road 601 and U.S. Highway 11. Turn left onto U.S. Highway 11 north.
29.7	Stop light for U.S. Highway 11 and Holiday Road in downtown Strasburg. Continue straight on U.S. Highway 11 north.
29.9	Turn left at stop light at intersection of U.S. Highway 11 and State Highway 55 east. Continue north on U.S. Route 11.
30.2	Turn left onto State Highway 55 west at intersection with U.S. Highway 11.
30.6	Type section for the Oranda Formation of Cooper and Cooper (1946) in vertical beds on right. The Oranda Formation, which was originally defined by its fossil content, is lithologically more akin to the Martinsburg Formation, and has been included within the Stickley Run Member of the Martinsburg by Epstein and others (in press). The slaty appearance of these rocks is due to highly developed cleavage that causes the rocks to weather in elongate fragments called "pencils."
31.7	Interchange for State Highway 55 and Interstate Highway 81. Continue west on State Highway 55.
34.2	Intersection of State Highway 55 and State Road 623. Turn left on State Road 623 and park in parking area immediately on right. Proceed on foot back to State Highway 55 to outcrop on north side of road just east of State Road 623.

STOP 3. CARBONATE CYCLES IN THE CONOCOCHEAGUE LIMESTONE

During the Late Cambrian, eastern North America was covered by a shallow sea. Limestone and dolostone of the Conococheague Limestone were deposited in restricted marine environments that ranged from subtidal (below tidal range) to supratidal (above mean high tide). Rock types representing these environments occur in 6- to 30-foot thick cycles and make up about 2,500 feet of the Conococheague. Figure 8 shows a generalized cycle. At the base of each cycle is an intraformational conglomerate produced from ripping up and redeposition of underlying beds during storms. These conglomerates are abundant in this exposure. This was followed by the growth of algal bioherms that were cut by tidal channels during subtidal and intertidal conditions. Next, high energy conditions of subtidal shoals are represented by cross-stratified grainstones followed by calmer conditions shown by silt-size sediment in the ribbon rock facies. The top of the cycle is capped by a laminated dolostone which may contain mudcracks indicating subaerial exposure. Smaller subcycles of two or three of these rock units may occur within a larger cycle. Several cycles can be seen in this roadcut. Two different models have been proposed for the formation of the cycles. The first explains each cycle by sea level fluctuations. Each cycle capped by a dolostone represents a regression while deeper water deposits indicate a transgression. This requires several hundred changes in sea level during deposition of the Conococheague. The second model infers a subsiding shelf wherein carbonate deposits build up more rapidly than subsidence of the shelf. When deposits reach sea level, production of carbonate sediment ceases. With continued subsidence, carbonate production resumes and the next cycle begins. Probably both of these models contributed to the deposition of the Conococheague cycles.

	Return to intersection of State Road 623 and State Highway 55. Turn left on State Highway 55 west.
36.5	The northwesternmost outcrop of the Elbrook Formation in the Massanutten synclinorium, part of the hanging wall of the North Mountain fault zone, occurs in the low area on right side of road. This marks the southeast limit of the North Mountain fault zone which extends to the northwest side of Little North Mountain in view straight ahead.
37.2	Intersection of State Highway 55 and State Road 623. Turn right on State Road 623.
37.3	Fork in road, bear right on State Road 714.

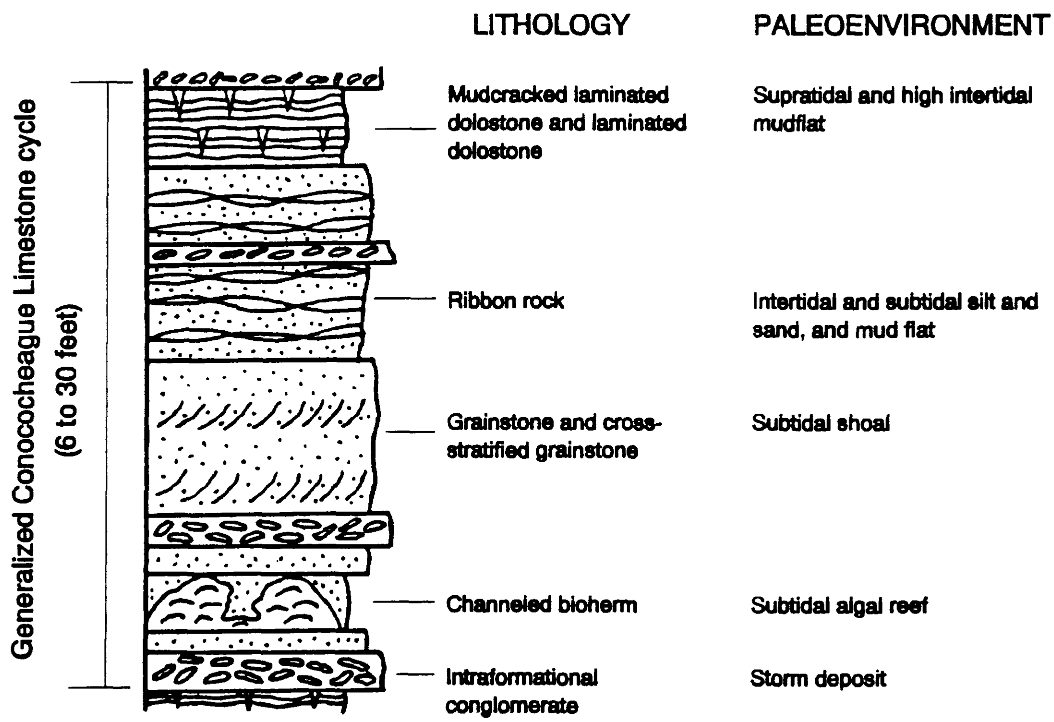


Figure 8. Typical peritidal cycle of carbonate rocks of the Upper Cambrian Conococheague Formation which can been observed along State Highway 55, just southeast of State Road 623 and 3 miles west of Strasburg, Mountain Falls 7.5-minute quadrangle, Shenandoah Co., VA. The 2,500-foot thick Conococheague is composed of many cycles and cycles within cycles representing subsidence of the carbonate platform and sea level fluctuations.

38.1 Outcrop of the New Market Limestone in a fault slice along North Mountain fault zone exposed on right side of road.

38.4 State Road 714, pull off road as far as possible.

STOP 4. FAULT SLICES IN THE NORTH MOUNTAIN FAULT ZONE

The North Mountain fault zone is a major thrust fault zone that extends from central Virginia to south-central Pennsylvania and contains Cambrian rocks in the upthrown block (hanging wall) and Silurian and Devonian rocks in the downthrown block (footwall). In this part of the central Appalachians, the North Mountain fault zone has the most displacement of any fault, thought to be as much as several tens of miles. The fault zone exposed in this area is as much as 2,500 feet wide and contains rocks from Ordovician to Devonian age in a series of fault slices. Rocks on the east side of the zone are generally upright, whereas rocks on the west side of the zone are generally overturned. Our interpretation is that the North Mountain fault zone developed along the overturned southeast limb of a syncline to the northwest and the adjacent upright limb of a faulted-out anticline to the southeast (see inset next to cross section on figure 9). The beds on the east part of the fault zone were derived from the upright limb, and the overturned beds in the west part of the zone were derived from the overturned limb of the syncline.

At this stop, as many as five fault slices can be identified, each containing progressively younger rocks toward the northwest (figure 9). The hillside to the southeast is capped by dolostone and limestone of the Cambrian Elbrook Formation which makes up the hanging wall of the fault zone. Two fault slices containing upright Middle Ordovician rocks (upper part of Beekmantown Group, New Market Limestone, Lincolnshire Limestone, and Edinburg Formation) occur on both sides of State Road 714 and extend to the creek to the west of the road. The lower part of the hillside to the west contains a fault slice of overturned rocks of the Middle Ordovician Stickley Run Member of the Martinsburg Formation and the middle and upper slope of the hillside contains a fault slice of overturned rocks of the upper part of the Middle and Upper Ordovician Martinsburg Formation. This hill is capped by a fault slice of the Silurian Tuscarora Sandstone. On the west side of the hill, a fault separates the Tuscarora from the overturned syncline containing Silurian and Devonian rocks in the footwall of the fault zone.

Continue on State Road 714.

39.1 Intersection of State Road 714 and State Road 606. Continue straight on State Road 714.

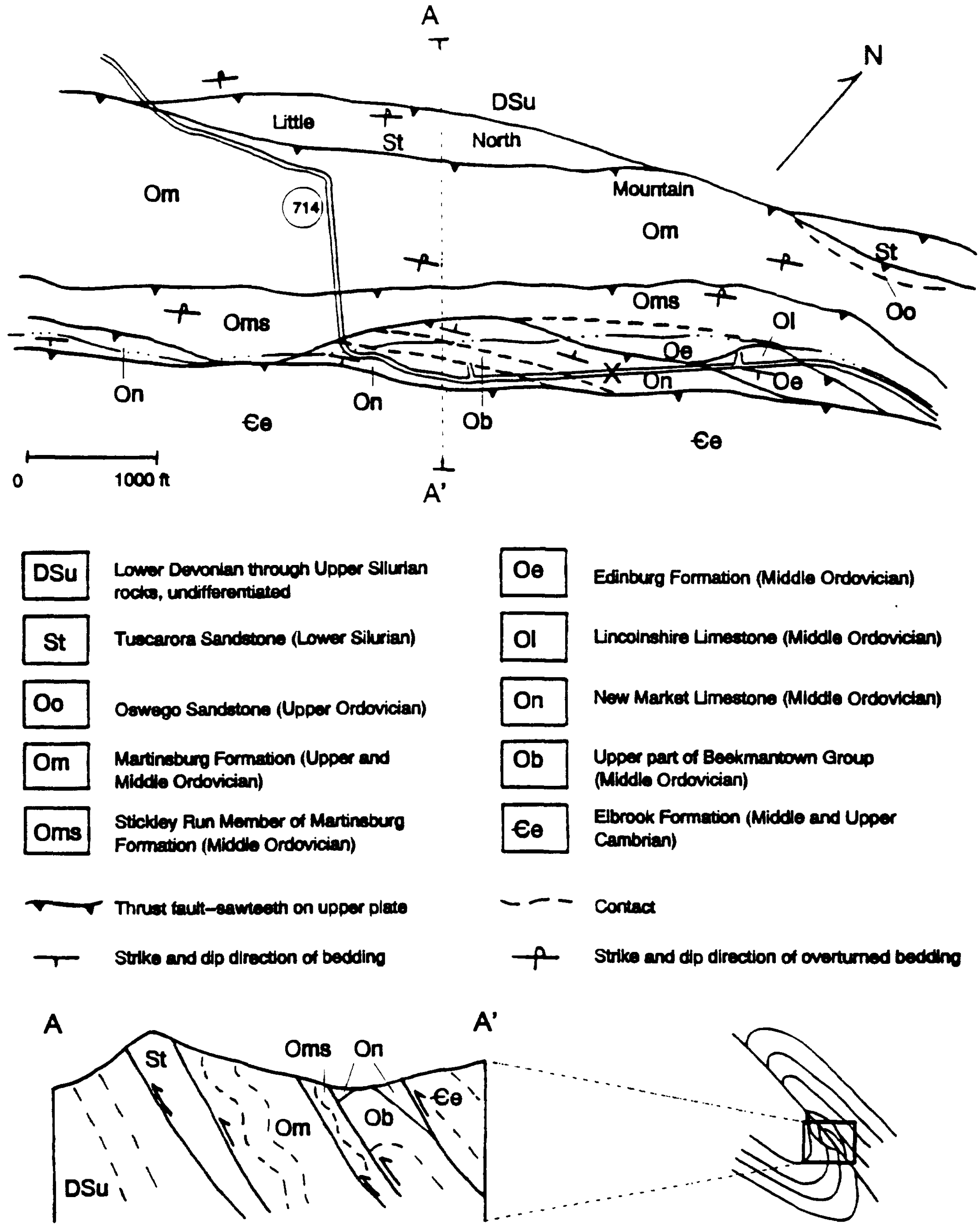


Figure 9. Geologic map and cross section of North Mountain fault zone along VA 714 and Little North Mountain, 1 mile east of Wheatfield, Shenandoah Co., Middletown 7.5-minute quadrangle, VA. X marks parking area along side of road (pull over as far as possible).

39.5	Intersection of State Road 714 and State Road 628. Turn left on State Road 628.
40.0	Cobbles from old terrace deposit weathering out of hillside on left side of road. This deposit is a relict of Cedar Creek from several thousand to more than 10,000 years ago when it flowed at a higher level.
40.2	Bridge over Cedar Creek. Note waterfall on left (up stream) and travertine deposit at waterfall. A spring about 0.5 mile upstream provides water that is supersaturated with respect to calcium carbonate. As the water is agitated at the waterfall, aeration causes the loss of carbon dioxide and precipitation of calcite in the form of travertine.
40.4	Intersection of State Road 628 and State Road 622 on right. Continue straight on State Road 628.
40.5	Intersection of State Road 628 and State Road 622 on left. Turn left on State Road 622.
40.6	Marlboro spring on right. This is the spring that provides calcium carbonate-rich water that forms the travertine in Cedar Creek at the waterfall.
41.6	Intersection of State Road 622 and State Road 623. Turn left on State Road 623.
41.9	State Road 623 at Baldwin Gap. Pull over on right side of road.

STOP 5. OVERTURNED SILURIAN SECTION AT BALDWIN GAP

Rocks exposed in Baldwin Gap are the footwall of the North Mountain fault zone and the overturned limb of the Mount Pleasant syncline of the Valley and Ridge Province. Because beds in the exposure are overturned, older beds overlie younger. This exposure contains various Silurian rocks cut by several high-angle reverse faults (fig. 10). An early interpretation of the stratigraphy in this exposure

GSW FIELDTRIP, STOP 5

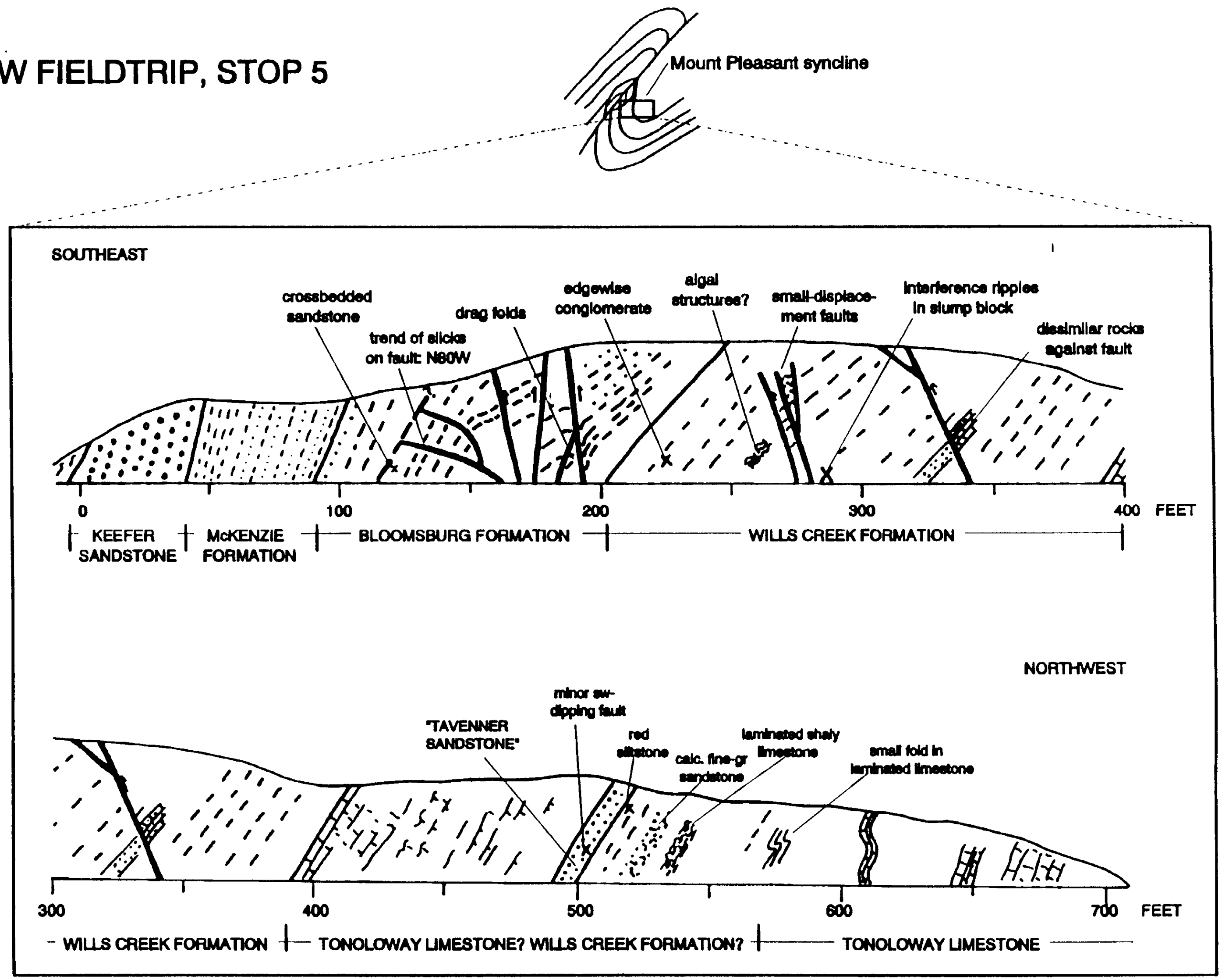


Figure 10. Geologic section at Baldwin Gap, near Marlboro, Va. Stratigraphic identifications differ from section published by Butts and Edmundson, 1966, p. 52

was published by Butts and Edmundson (1966) (table 1). An alternative interpretation of the stratigraphy is shown in table 2 and figure 10.

At the east end of the outcrop the oldest unit exposed is the Keefer Sandstone, a gray quartzite that is pebbly in places. The lower contact of the Keefer is probably a fault within the North Mountain fault zone. Sedimentologically, the Keefer was deposited in a beach environment. The unit stratigraphically above the Keefer, the McKenzie Formation, consists of siltstone and shale deposited in a deeper subtidal environment. Redbeds of the stratigraphically overlying Bloomsburg Formation represent shallow marine to mudflat deposition. Several high-angle reverse faults cutting the Bloomsburg Formation can be recognized by offset beds and small drag folds in rocks adjacent to the faults. These faults formed in the same time interval as the North Mountain fault zone but show movement at a high angle to the major fault and dip in the opposite direction. Stratigraphically above the Bloomsburg, the Wills Creek Formation consists of shale, siltstone, and limestone deposited in a tidal-mudflat environment. The introduction of limestone in the Wills Creek marks the transition from strictly clastic deposition to carbonate deposition in the stratigraphically overlying Tonoloway Limestone, which was deposited under intertidal conditions.

	Turn around and return to intersection of State Road 623 and State Road 622.
42.2	Intersection of State Road 623 and State Road 622. Turn right on State Road 622.
43.3	Intersection of State Road 623 and State Road 628. Turn left on State Road 628.
45.6	Intersection of State Road 628 and State Road 631. Turn right on State Road 631.
49.0	Note the lime plant on the right side of road beyond the railroad tracks. New Market Limestone from nearby quarries is hydrated in this plant, producing calcium hydroxide that is used in waste treatment facilities for small local municipalities. Lime dust is very noticeable on all the buildings in the immediate area. The New Market Limestone, which is as much as 98 percent calcium carbonate, is the most economically important industrial mineral commodity in the Shenandoah Valley and is used in the manufacture of steel, paper, aluminum, glass, and plastic. Also, the limestone is quarried for use as a waste stream

Table 1. Geologic section of Baldwin Gap (stop 5) through Little North Mountain (from Butts and Edmundson, 1966).

	Thickness Feet
NEW SCOTLAND AND KEYSER LIMESTONES (148 + feet); covered at top	
26. Limestone, cherty	80+
25. Limestone	30±
24. Limestone, gray, medium-grained	10
23. Limestone, medium-grained, nodular-weathering	28
TONOLOWAY FORMATION (192 ± feet)	
22. Limestone, fine-grained, laminated, shaly	26
21. Covered	12
20. Limestone, impure	53
19. Limestone, impure; scattered chert; some beds weather cobbly	32
18. Limestone, cherty	2
17. Limestone, gray, fine-grained; some impure partings	42
16. Limestone, shaly, laminated	25
WILLS CREEK FORMATION (181 ± feet)	
15. Sandstone, massive, thick-bedded (Tavenner sandstone member)	9
14. Limestone, shaly	57
13. Limestone, shaly; partly covered	51
12. Sandstone, brown	4
11. Shale, red	5
10. Sandstone, brown	5
9. Shale and intercalated thin-bedded limestone	24
8. Shale and sandstone	20
7. Shale, red	6
BLOOMSBURG FORMATION (160 feet); may include some Clinton in lower part	
6. Sandstone and shale; partly covered; red float	25
5. Largely covered; some red float	26
4. Sandstone and shale, red; some sandstones are thick bedded	62
3. Covered	47
TUSCARORA FORMATION; tentatively interpreted as having fault contacts	
2. Sandstone, gray, medium- to thick-bedded	40
MARTINSBURG FORMATION	
1. Covered; shale noted along strike north and south of State Road 623	76
ELBROOK FORMATION, in upper plate of North Mountain fault	

Table 2. Alternative interpretation of geologic section at Baldwin Gap (stop 5).

Tonoloway Limestone Medium-gray to medium-dark-gray laminated and crinkly to thin-bedded calcareous shale and limestone with thin calcareous shale laminae. At least 170 ft (50 m) thick. Top covered.

Tonoloway Limestone/Wills Creek Formation At 390-foot marker is a 2-foot-thick bed of medium-dark gray, fine-grained limestone overlain by about 20 feet (6 m) of crinkly laminated limestone which looks like the Tonoloway Limestone elsewhere. This is succeeded by medium-gray to medium-dark-gray laminated and crinkly to thin-bedded calcareous shale and limestone, similar to rocks in the underlying Wills Creek. The Tavenner Sandstone of Butts and Edmundson (1966), is a 10-foot crossbedded, medium-grained, light-olive-gray sandstone near the top of this sequence. Unit is about 140 ft (43 m) thick.

Wills Creek Formation At the base is a medium-gray, slightly calcareous, laminated shale. Overlain by thin-bedded to laminated, olive-gray, very fine- to medium-grained sandstone; medium-dark-gray to olive-gray, very fine-grained limestone; intraclastic limestone (edgewise conglomerate); medium-dark-gray and greenish-gray to light-olive-gray shale; and crinkly (algal?), laminated, medium-dark gray calcareous shale. About 140 ft (43 m) thick, but section is faulted.

Bloomsburg Formation Base placed at moderate-grayish-red siltstone. Overlain by grayish-red, grayish-purple, medium-gray, light-olive-gray to olive-gray, and greenish-gray siltstone to very fine-grained sandstone and some thin-bedded and crossbedded medium-gray, medium-grained sandstone. Upper contact with the Wills Creek Formation (at 210 foot marker) is marked by partly crossbedded and channeled, mottled greenish-gray and grayish-red, very fine- to fine-grained sandstone. About 110 ft (35 m) thick, but section is extensively faulted and much of the section may be structurally thinned.

McKenzie Formation Olive-gray fissile shale at base interbedded with olive-gray, fossiliferous (poorly preserved brachiopods), siliceous siltstone; light-olive-gray shale at top. About 40 ft (12 m) thick, but many bedding surfaces are sheared and the thickness may be altered by faulting.

Keefer Sandstone Medium-light gray, coarse-grained to pebbly vitreous quartzite at base, grading up to medium-gray, medium-grained quartzite and olive-gray very fine-grained sandstone. Lower and upper contacts covered. About 40 ft (12 m) thick.

neutralizer for the coal mining industry, for construction gravel and road gravel, and agricultural lime.

49.5 Stop light at intersection of State Road 631 and U.S. Highway 11. Turn left onto U.S. Highway 11 north.

52.5 Interchange for U.S. Highway 11 and State Highway 37 south. Turn left onto ramp leading to State Highway 37 south.

53.1 Interchange for State Highway 37 and Interstate Highway 81. Turn left at stop light on entrance ramp for Interstate Highway 81 north.

56.5 Interchange for Interstate Highway 81 and U.S. Highway 50. Continue north on Interstate Highway 81.

58.5 Interchange for Interstate Highway 81 and State Highway 7, exit 315, Winchester. Take exit for State Highway 7.

58.8 Bear right at top of exit ramp for State Highway 7 west to Winchester.

59.0 Make left at stop light into Shoneys Restaurant parking lot. End of trip.

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Cooper, B.N., and Cooper, G.A., 1946, Lower Middle Ordovician stratigraphy of the Shenandoah Valley, Virginia: Geological Society of America Bulletin, volume 57, p. 35-114.

Epstein, J. B., Orndorff, R.C., and Rader, E.K., in press, The Stickley Run Member of the Martinsburg Formation, Shenandoah Valley, northern Virginia: U.S. Geological Survey Bulletin.