Guidebook for the

11th Annual Field Trip

of the Harrisburg Area Geological Society

May 9, 1992

Paleozoic Geology of the Paw Paw-Hancock Area of Maryland and West Virginia

by

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USGS 7 1/2 minute quadrangles

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Cover Photo: Anticline in Silurian Bloomsburg Formation. From Stose and Swartz (1912). The anticline is visible from the towpath of the C & O Canal at Roundtop Hill (Stop # 1).

Guidebook copies may be obtained by writing:

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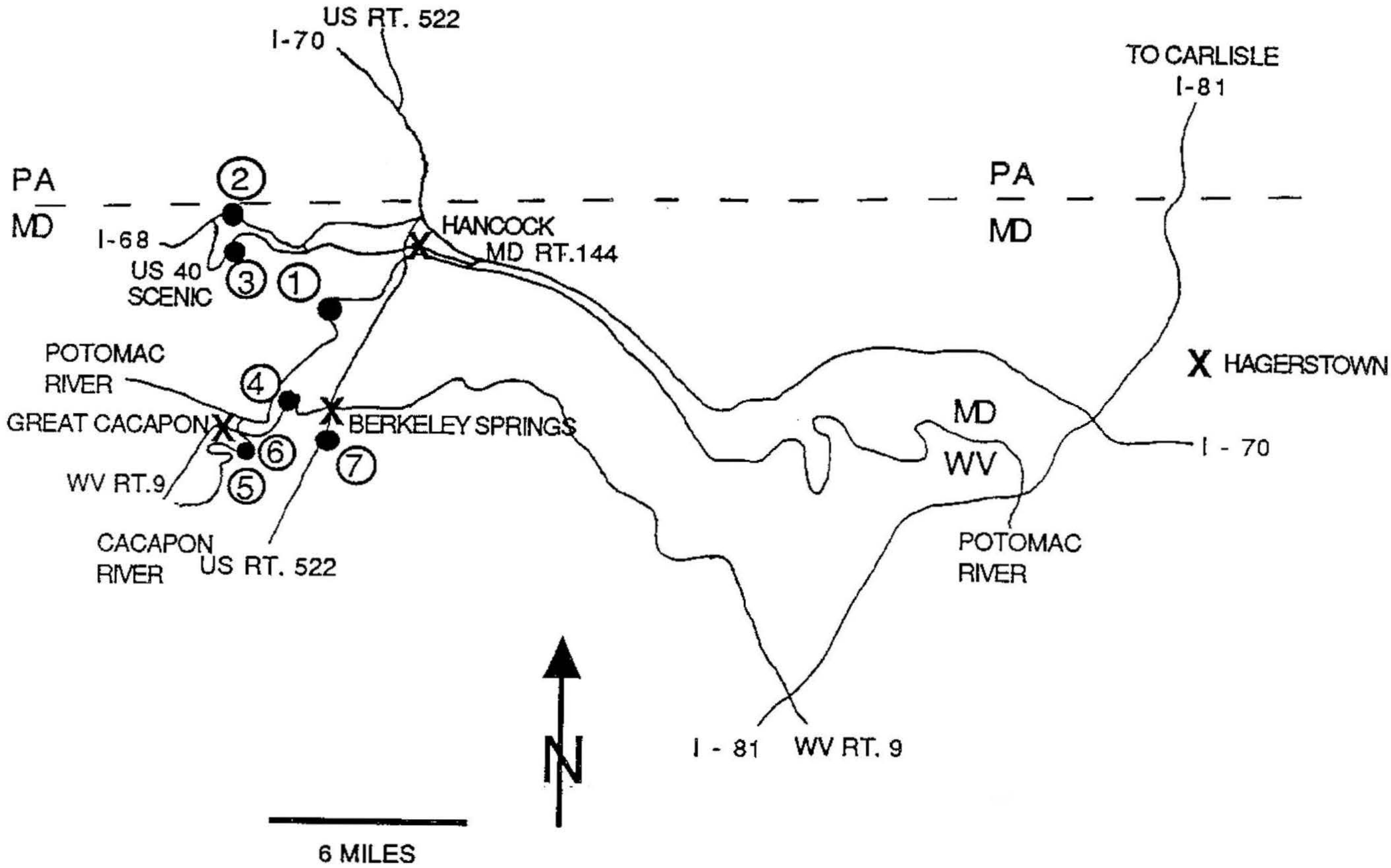
INTRODUCTION

This year's field trip is the first by the Harrisburg Area Geological Society to visit the geology of Maryland and West Virginia. We will examine the Paleozoic geology of the Valley and Ridge physiographic province in western Maryland and eastern West Virginia (Figure 1). The trip will focus on the structure, stratigraphy, and sedimentology of the excellent exposures of Silurian and Mississippian strata in the Paw Paw and Hancock quadrangles as originally described by Stose and Swartz (1912).

Figure 1. Map showing field trip stop locations.



The stops on this field trip focus on two aspects of the area's geologic history. First, is the deposition of the marine, marginal marine, and terrestrial sediments from the Late Silurian through the Early Mississippian (Figure 2). At the time of deposition of these strata, the east coast of the North American continent was located at a paleolatitude of 15°-30°S (Scotese and McKerrow 1990). There was a shallow sea (Appalachian Basin) between the craton to the west and an island arc highland to the

Figure 2. Stratigraphic section (Modified from Cardwell et al. 1968; Cleaves et al. 1968; Edwards 1978).

STOP #	PERIOD	FORMATION
4	Quaternary	alluvium
	Mississippian	Greenbrier Formation
2		Purslane Sandstone
2 & 3		Rockwell Formation
	Devonian	Hampshire Formation
		Chemung Formation
		Parkhead Sandstone
		Brallier Formation
		Harrell Shale
		Mahantango Formation
		Marcellus Formation
7		Oriskany Sandstone
		Helderberg Formation
		Keyser Limestone
	Silurian	Tonoloway Limestone
1		Wills Creek Shale
1		Bloomsburg Formation
		McKenzie Formation
5 & 6		Rochester Shale
5 & 6		Keefer Sandstone
5 & 6		Rose Hill Formation
4		Tuscarora Sandstone
	Ordovician	Juniata Sandstone

east. Deposition of these units occurred in this sea. Sediment accumulated in various environments as facies migrated in response to changes in sea level and rate of sediment input from the east.

The second aspect of the area's geologic history that this trip focuses on is the deformation of these rock units. The main stage of deformation here occurred during the late Paleozoic Alleghanian Orogeny. This resulted in often intense folding of the rocks that now underlie the Valley and Ridge physiographic province. Since the late Paleozoic, this region has been above sea level and has been exposed to subaerial weathering.

The Valley and Ridge physiographic province is noted for its classic structural style. This style is marked by closely spaced parallel folds and faults with remarkable uniformity along strike which in this area trends generally N25-30°E. The topography in the area is controlled by the distribution of rocks of varying resistance to erosion. The more resistant rocks are generally sandstones which form the ridges. The less resistant limestones and shales form the valleys.

The Potomac River is the main drainage feature of the region. In this area it is often tightly meandering. The bends are generally symmetrical and deeply incised. Abandoned incised meanders are quite common in the Potomac (Stose and Swartz 1912, Fig. 10; Grimsley 1916, Fig. 5; Fitzpatrick 1987, Fig. 1).

Alluvial terrace gravels occur in patches along the Potomac River (Stose and Swartz 1912) but have received little attention since their mapping. The drainage pattern is a typical trellis arrangement resulting from the outcrop pattern of strata of alternating resistance to erosion.

ROAD LOG

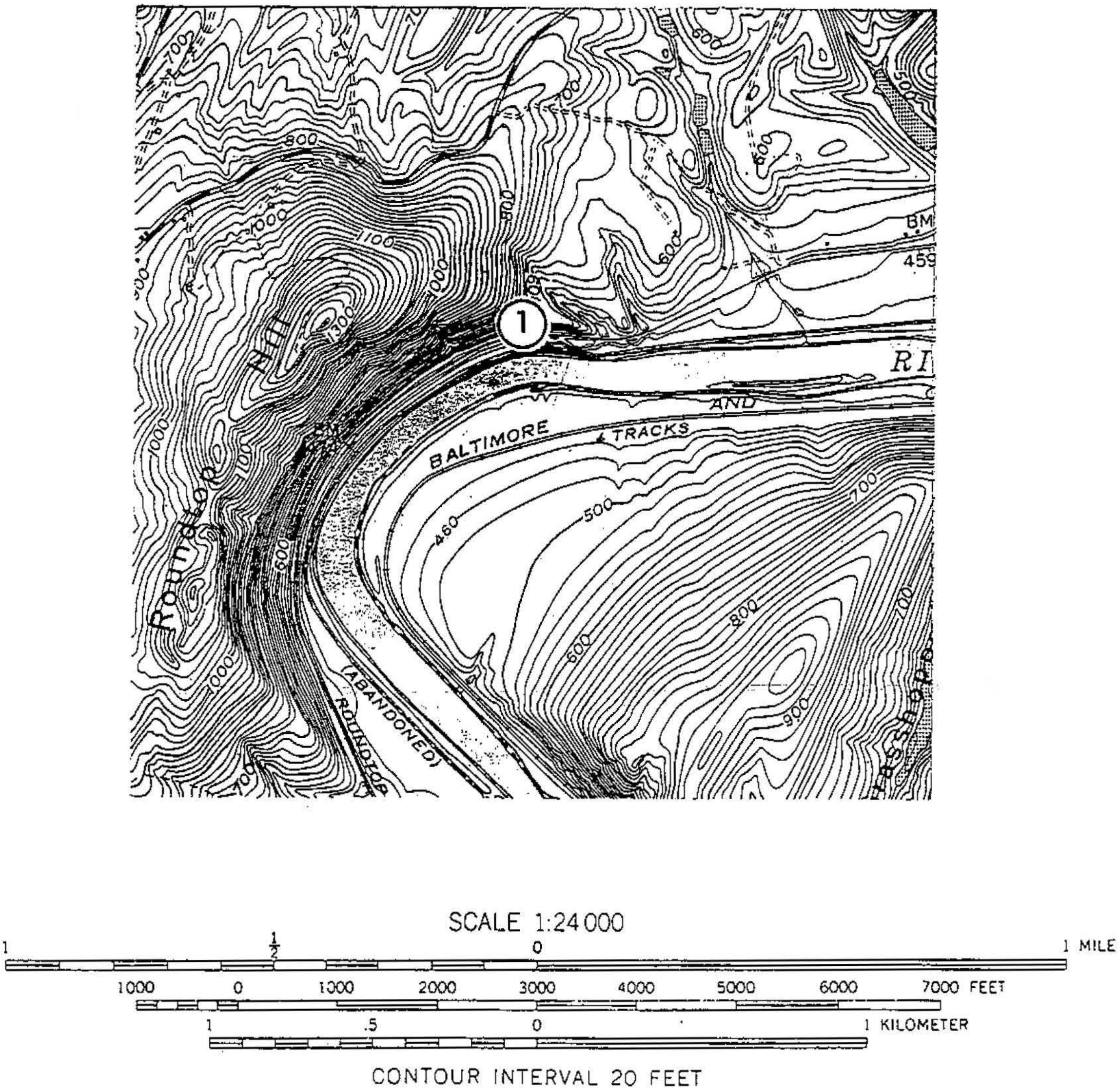
NOTE: The road log starts in Hagerstown, MD at the intersection of I-81 and I-70. Distance via I-81 from Carlisle, PA to start the road log is 55 miles. All road log distances are in miles.

0.0	0.0	I-81 interchange with I-70 (exit #3 from I-81) in Hagerstown, MD. Head west on I-70 toward Cumberland, MD. On Cambro-Ordovician carbonates in the Great Valley.
1.5	1.5	Exit #24
1.6	0.1	Leave dolomite of Ordovician Rockdale Run Formation and enter shale of Ordovician Martinsburg Formation. This is a fault contact. Martinsburg outcrop in road cut on right (north).
3.0	1.4	Cross over Conococheague Creek which originates near Caledonia in Pennsylvania and flows southward down the Great Valley to the Potomac River.
4.4	1.4	Leave Ordovician Martinsburg Shale and enter Ordovician Chambersburg Limestone. Chambersburg outcrop in road cut on right (north).
8.1	3.7	Exit # 18.
10.6	2.5	Leave Ordovician Conococheague Formation and enter Devonian Marcellus Formation. This contact is a major thrust fault contact called the North Mountain fault. It marks the end of the Great Valley physiographic province and the beginning of the Valley and Ridge physiographic province. Note the change in vegetation and topography. The ridge to the right (north) is held up by the Devonian Oriskany Sandstone and the Silurian Tuscarora Sandstone.
13.0	2.4	Ridge of Devonian Oriskany Sandstone.
13.8	0.8	Exit # 12.
16.3	2.5	Cross over Licking Creek which flows into the Potomac River 0.25 miles to the left (south).
17.6	1.3	Devonian Chemung Formation red beds outcrop in syncline on right (north).
19.7	2.1	Exit # 5.
22.6	2.9	Exit to the left at the MD Route 144 - Hancock, MD exit (# 3).
23.0	0.4	Go right (west) at stop sign (west on MD Route 144) toward Hancock, MD.
23.3	0.3	Cross over Tonoloway Creek which flows into the Potomac River 0.1 miles to the left (south).
24.5	1.2	Go straight through first stop light in Hancock, MD which is Taney Street.

24.7	0.2	Go left (south) at second stop light in Hancock, MD which is Pennsylvania Avenue.
24.8	0.1	Go right (west) on Berm Road. Follow Berm Road straight along the Chesapeake and Ohio (C & O) canal so that the canal is to your left (south).
25.0	0.2	Cross under US Route 522 bridge.
26.8	1.8	Cross over old Western Maryland Railroad and make an immediate left (west) onto Locher Road.
27.4	0.6	Park where Locher Road turns to the right (north). Walk west roughly 0.2 miles along the old Western Maryland Railroad bed to Stop # 1.

STOP # 1. Railroad cut, SW 1/4 Hancock quadrangle (Figure 3).

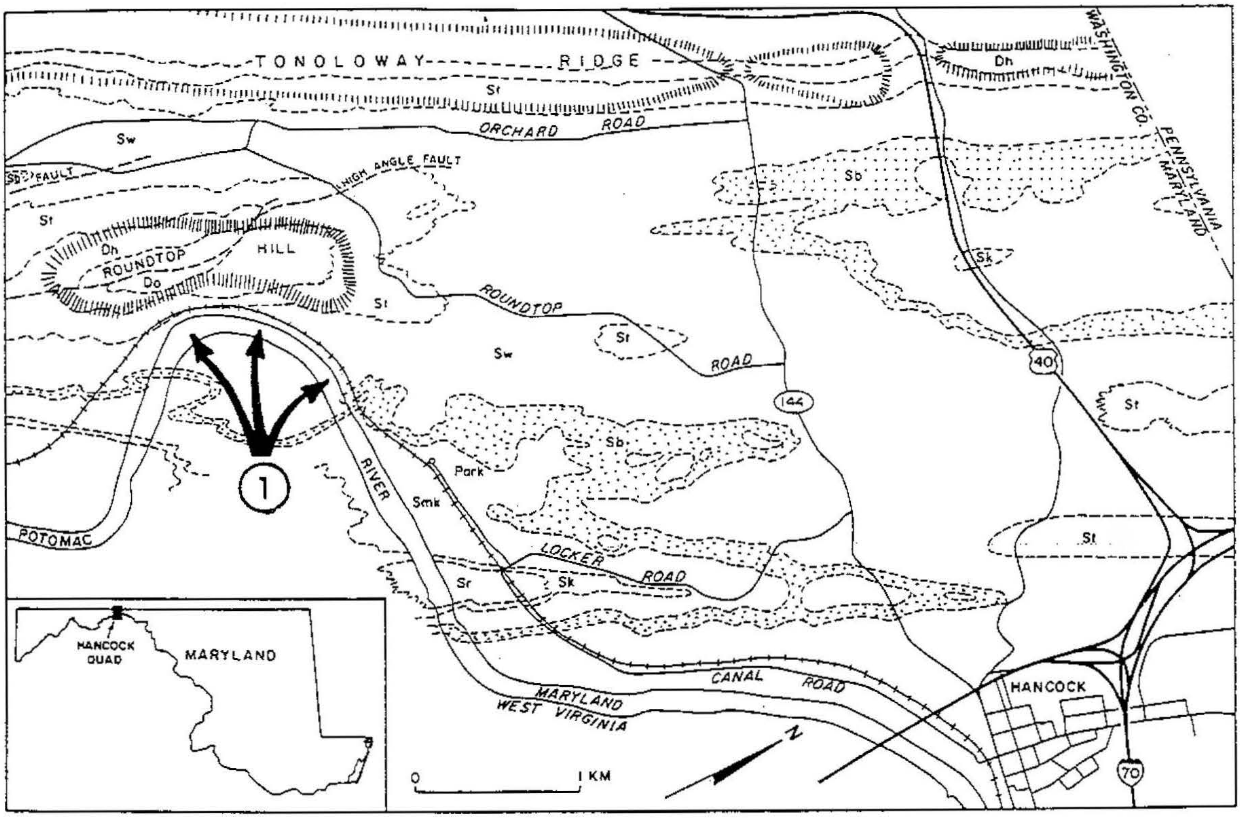
Figure 3. Location map for Stop # 1.



STOP 1 ROUNDTOP HILL

Cloos (1951a, p. 78) referred to the Roundtop Hill outcrops as displaying "some of the most beautiful folds and other structures in the Appalachian region." The Roundtop Hill exposure reveals outcrops of the Silurian Bloomsburg Formation and Wills Creek Shale (Swartz 1923a; Cleaves et al. 1968; Edwards 1978; Figure 4). Roundtop Hill is located in the Cacapon Mountain anticlinorium which plunges gently to the north (Glaser 1987). The Silurian rocks in the Cacapon Mountain anticlinorium are exposed in a belt 2.5 miles wide between Cove ridge to the southeast and Tonoloway ridge to the northwest. The Wills Creek Shale is completely exposed at Roundtop Hill and it dominates the section. The Bloomsburg Formation underlies the Wills Creek Shale but is relatively thin here.

Figure 4. Geologic map for Stop # 1. St = Tuscarora Sandstone, Sk = Keefer Sandstone, Sr = Rochester Shale, Smk = McKenzie Formation, Sb = Bloomsburg Formation, Sw = Wills Creek Shale, St = Tonoloway Limestone, Dh = Helderberg Formation, and Do = Oriskany Sandstone (Modified from Glaser 1987, Fig. 1).



The Bloomsburg Formation consists of dark red, interbedded sandstones and shales with well-developed fracture (fan) cleavage generally perpendicular to bedding (Swartz 1923b; Cloos 1951a; Edwards 1978). The age of the Bloomsburg Formation is not well constrained due to the paucity of fossils. Its Silurian age is based on occasional brachiopods and ostracods in some of the thin-bedded marine shales (Swartz 1923b; Amsden 1951). The Bloomsburg Formation has been interpreted as a fluvial deltaic environment (Alling and Briggs 1961).

The Wills Creek Shale rests unconformably on the Bloomsburg Formation (Cloos 1951a). The Wills Creek Shale consists of olive-gray to yellow-gray calcareous shales, calcareous mudstones, and argillaceous limestones with several sandstone beds (Swartz 1923b; Cloos 1951a; Edwards 1978). Mud cracks, ripple marks, and salt crystal imprints can be found. The Wills Creek Shale has a distinctive and diverse brachiopod, ostracod, pelecypod, and eurypterid fauna indicative of the Middle Silurian (Stose and Swartz 1912; Swartz 1923b; Amsden 1951). The lithology, fauna, mud cracks, ripple marks, and salt crystal pseudomorphs all indicate that the Wills Creek Shale was deposited in shallow marine, intertidal conditions.

The argillaceous limestones in the Wills Creek Shale were mined here for natural cement from 1863-1909. The Round Top Cement Company kiln, whose remains are still visible along the C & O Canal, burned down in 1903 (Cloos 1951a,b). The cement was packed in wooden barrels and sent by cable across the Potomac to the Baltimore and Ohio Railroad on the opposite bank or they were shipped down the canal via barge.

The C & O Canal stretches for 185 miles from Washington, DC to Cumberland, MD. It was designed as a commercial water passage along the often impassable Potomac River. Materials were moved by mules walking along a towpath pulling barges. 74 locks were needed to overcome the 605 foot elevation change from end to end. The canal operated from the 1831 to 1924. It closed due to competition from the railroads and costly flood damage.

The outcrops here provide good insight into the mechanics of folding, formation of cleavage, thrusting, and deformation of bedded rocks. The more competent sandstone and siltstone beds of the Bloomsburg Formation exhibit flexure folds with constant bed thickness and bedding plane slippage (Glaser 1987). The weaker shales and thin-bedded limestones of the Wills Creek Shale exhibit abundant thickening of beds into the fold crests and display intense subparallel flow cleavage (Glaser 1987).

Cleavage is present in nearly all the rocks at Roundtop Hill, but it is most conspicuous in the shales and siltstones of the Bloomsburg and lower Wills Creek formations. Cleavage here is generally oriented normal to bedding. It fans the fold producing what Cloos (1951a) termed axial plane cleavage and what Glaser (1987) termed fanning cleavage. Geiser (1974) attributes this style of cleavage to pressure solution, not brittle failure associated with fracture cleavage.

Small scale thrust faults are also common here. Many of these faults cut the beds at a low angle producing a wedge-shaped blocky pattern (Cloos 1964). Slickensides on bedding planes are common, and are usually perpendicular to fold axes. The host rocks for the faults are usually massive siltstones or coarse shales in the Bloomsburg Formation.

The first outcrops are the red shales and sandstones of the Bloomsburg Formation. This first exposure is a complexly faulted anticline (Glaser 1987, Fig. 21). Note the repeated thrusting of the thin sandstone bed in the lower portion of the section and the excellent fanning cleavage in the adjacent shales.

After passing through a sequence of easily eroded, poorly consolidated mudstones and shales of the Wills Creek Shale, there is a tightly folded syncline. Note the well-developed axial plane cleavage and low angle thrust faults in the west limb.

The second anticline shows a classic example of the different behaviors of competent and incompetent beds during folding. The less competent shales have flowed into the crest of the anticline while the more competent red siltstone has thickened into the crest by repeated low angle thrust faults (Glaser 1987). Note the bedding plane slickensides caused by the sliding of siltstone beds past one another.

There are nice mud cracks in the last exposure on the left before you reach the old cement kiln. Before continuing west down the railroad bed, there a two spectacular anticlines in the Bloomsburg Formation that are only visible from the C & O canal towpath. To see them you must climb down the steep embankment between the railroad bed and the towpath. One of the anticlines is figured on the front cover of this guidebook.

30 m past the old cement kiln chimney is a paired syncline/anticline. Note the limbs are crowded with small kink folds. West of this is the entrance to the largest cement mine. It is excavated into the core of a large, tight anticline. The tunnel plunges steeply down the fold hinge and opens into a large chamber. The last stop is further down the railroad tracks on the right (north) side where a small thrust fault has created a small snake head anticline.

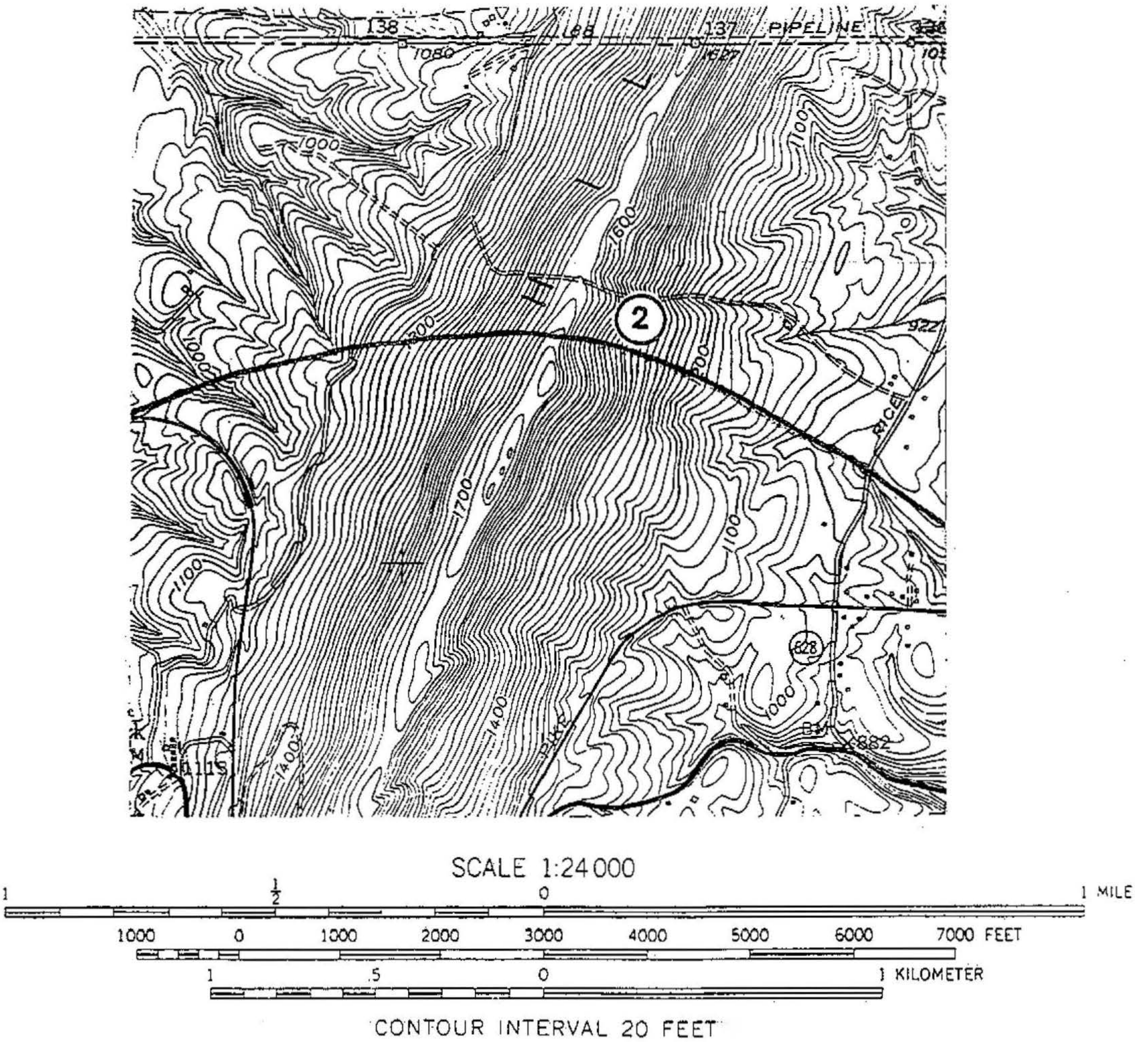
For a more complete description of the exposures, see Glaser (1987).

27.4	0.0	Return the way you came back to Hancock, MD.
27.9	0.5	Turn right (south) where Locher Road turns left (north) and immediately cross over the old Western Maryland Railroad.
29.7	1.8	Cross under US Route 522 bridge.
29.9	0.2	Turn left (north) on Pennsylvania Avenue in Hancock, MD.
30.0	0.1	Turn left (west) on Main Street (MD Route 144) in Hancock, MD.
30.2	0.2	Turn right (north) on Virginia Avenue and immediately turn left (west) at stop sign on High Street in Hancock, MD.
30.3	0.1	Turn right (north) on US Route 522. Get in left lane.
31.2	0.9	Exit left (# 1A) for I-68 west to Cumberland, MD.
31.8	0.6	Silurian Tonoloway Limestone outcrops in road cut on right (north).
33.2	1.4	First view of Sideling Hill road cut straight ahead.
33.8	0.6	Devonian Oriskany Sandstone outcrops in road cut on left (south).
34.8	1.0	Exit # 77.
37.4	2.6	Exit right for Sideling Hill Exhibit Center.

37.6	0.2	Park at Sideling Hill Exhibit Center for Stop # 2. After examining the geology, we will eat lunch here.

STOP # 2. Road cut, NW 1/4 Bellegrove quadrangle (Figure 5).

Figure 5. Location map for Stop # 2.

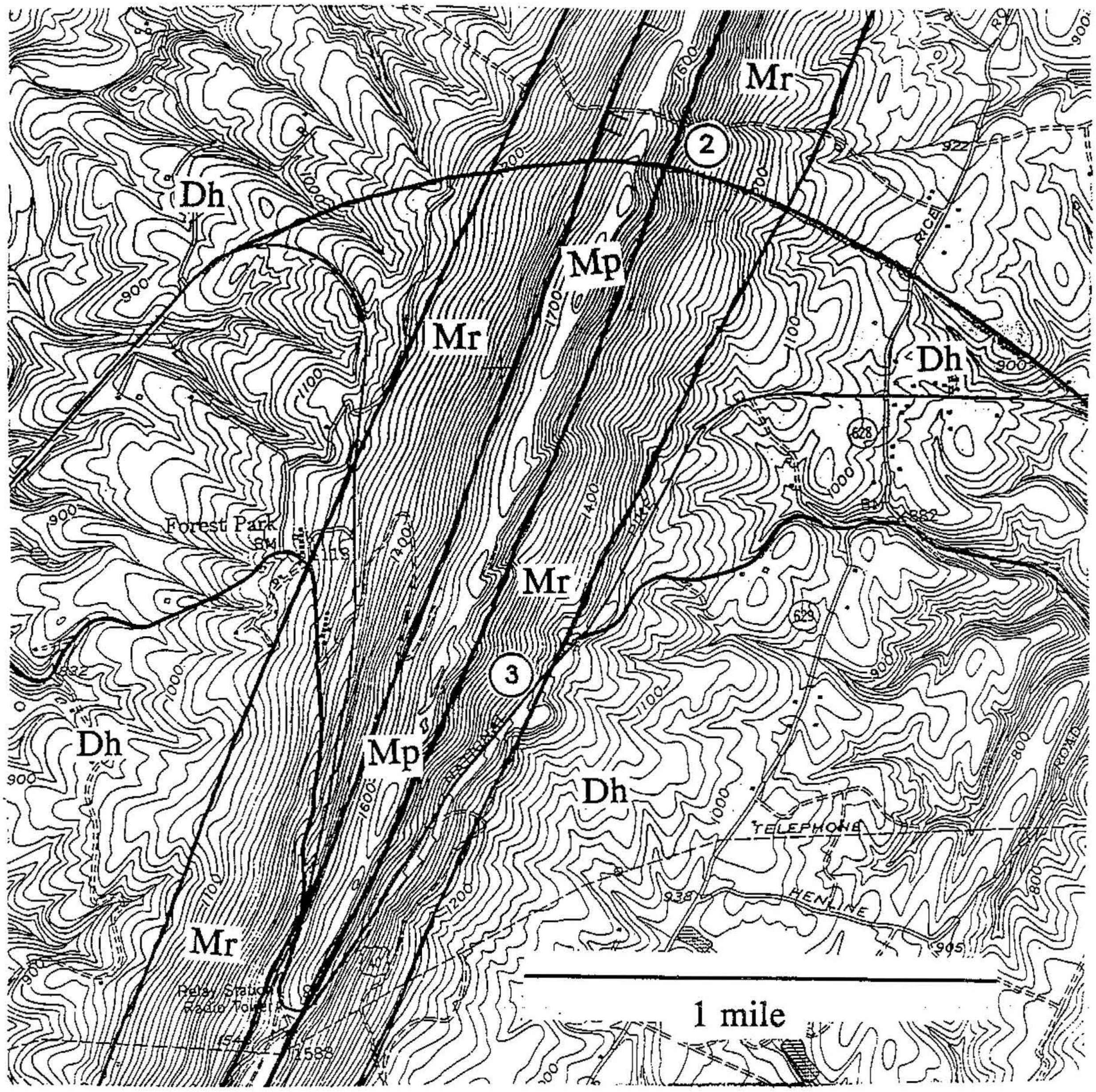


STOP 2 SIDELING HILL ROAD CUT

This spectacular road cut was excavated in 1983 for the new Interstate 68. Photographs of it have been on the cover of *Geotimes* and the *AAPG Bulletin*. Inside the exhibit center on the first level there is a display identifying the ridges of the Valley and Ridge physiographic province visible to the east. On the top floor is a geology exhibit on the road cut.

The Sideling Hill outcrops are of the Mississippian Pocono Group containing the Rockwell Formation and the Purslane Sandstone (Stose and Swartz 1912; Cleaves et al. 1968; Figure 6). Sideling Hill is a long syncline with an horizontal axis

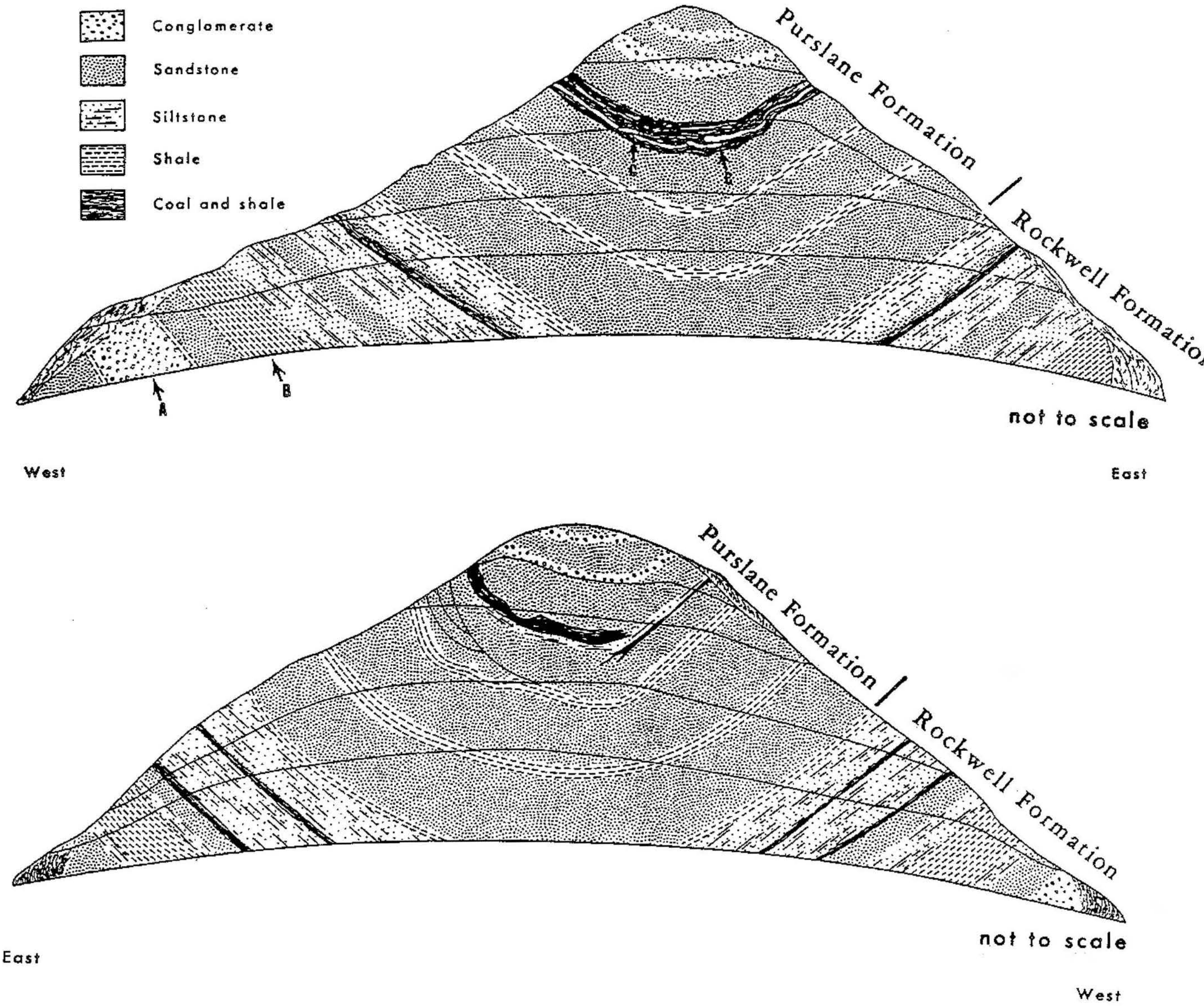
Figure 6. Geologic map for Stops # 2 & 3. Dh = Hampshire Formation, Mr = Rockwell Formation, and Mp = Purslane Sandstone (Modified from Edwards 1978).



(Cloos 1951c; Figure 7) that extends 15 miles north into Pennsylvania and 20 miles south into West Virginia.

The Rockwell Formation is composed of interbedded sandstone, siltstone, and shale with an occasional thin coal bed and diamictite (Stose and Swartz 1912; Cloos 1951a; Cleaves et al. 1968; Edmunds et al. 1979; Bjerstedt 1986; Brezinski 1989b,c; Schwarz 1991). Plant fossils (e.g., *Lepidodendron*) can be found near the base of the formation (Stose and Swartz 1912).

Figure 7. Sketch of outcrop at Stop # 2 (From Brezinski 1989a).



The Purslane Sandstone is a green-gray to white, thick-bedded, resistant, ridge-forming unit composed of cross-bedded sandstone and conglomerate interbedded with red mudstone and coaly shale (Stose and Swartz 1912; Cloos 1951a; Cleaves et al. 1968; Edmunds et al. 1979; Bjerstedt 1986; Brezinski 1989b,c; Schwarz 1991). It caps the syncline at Sideling Hill. It also contains plant fossils of *Lepidodendron* (Stose and Swartz 1912)

The age of the Pocono Group is Lower Mississippian based on the presence of *Lepidodendron* plant fossils (Amsden 1951) and litho-stratigraphic relationships of adjacent formations (Bjerstedt 1986). The base of the Pocono Group (Rockwell Formation) is marked by a distinctive floral succession indicating a change from a Devonian flora to a Mississippian one (Weller et al. 1948). The Rockwell Formation in Maryland contains the distinctive *Adiantites* floral zone (Read 1955). This flora is characterized by primitive vascular plants such as the club mosses (lycopsids), horsetails (sphenopsids), and seed ferns (pteridosperms).

Grain size distributions, isopach maps, and paleocurrent data indicate the sediment transport direction was toward the northwest from a southeastern source area (Pelletier 1958; Brezinski 1989c). These rocks have been interpreted as representing fluvial and swamp environments on a deltaic, coastal plain (Pelletier 1958; Edmunds et al. 1979; Bjerstedt 1986; Brezinski 1989b,c). These fluvial deposits grade into marine deposits to the northwest as indicated by the lithologic changes as well as the presence of brachiopods and the trace fossil *Arthrophycus* to the northwest (Barrell 1913; Pelletier 1958).

For a more complete description of the exposures, see Bjerstedt (1986).

37.6	0.0	Leave the Sideling Hill Exhibit Center by heading west on I-68 through the Sideling Hill road cut toward Cumberland, MD.
39.8	2.2	Devonian Chemung Formation red bed outcrops in road cut on right (north).
40.5	0.7	Exit right (exit # 72) for US Scenic Route 40.
40.7	0.2	Turn left (south) at stop sign and cross over I-68.
40.8	0.1	Turn left (east) at stop sign onto US Scenic Route 40.
42.9	2.1	Turn right (south) at stop sign and stay on US Scenic Route 40. This will go up the west limb of the Sideling Hill syncline.
43.7	0.8	Scenic overlook on right (west).
44.1	0.4	Ridge crest of Sideling Hill. The road curves sharply to the left and goes down the east limb of the syncline.
44.9	0.8	Pull off to the right and park next to the highway department facility for Stop # 3. Walk across the road. The outcrop is immediately up the hill and is located behind chain link fences.

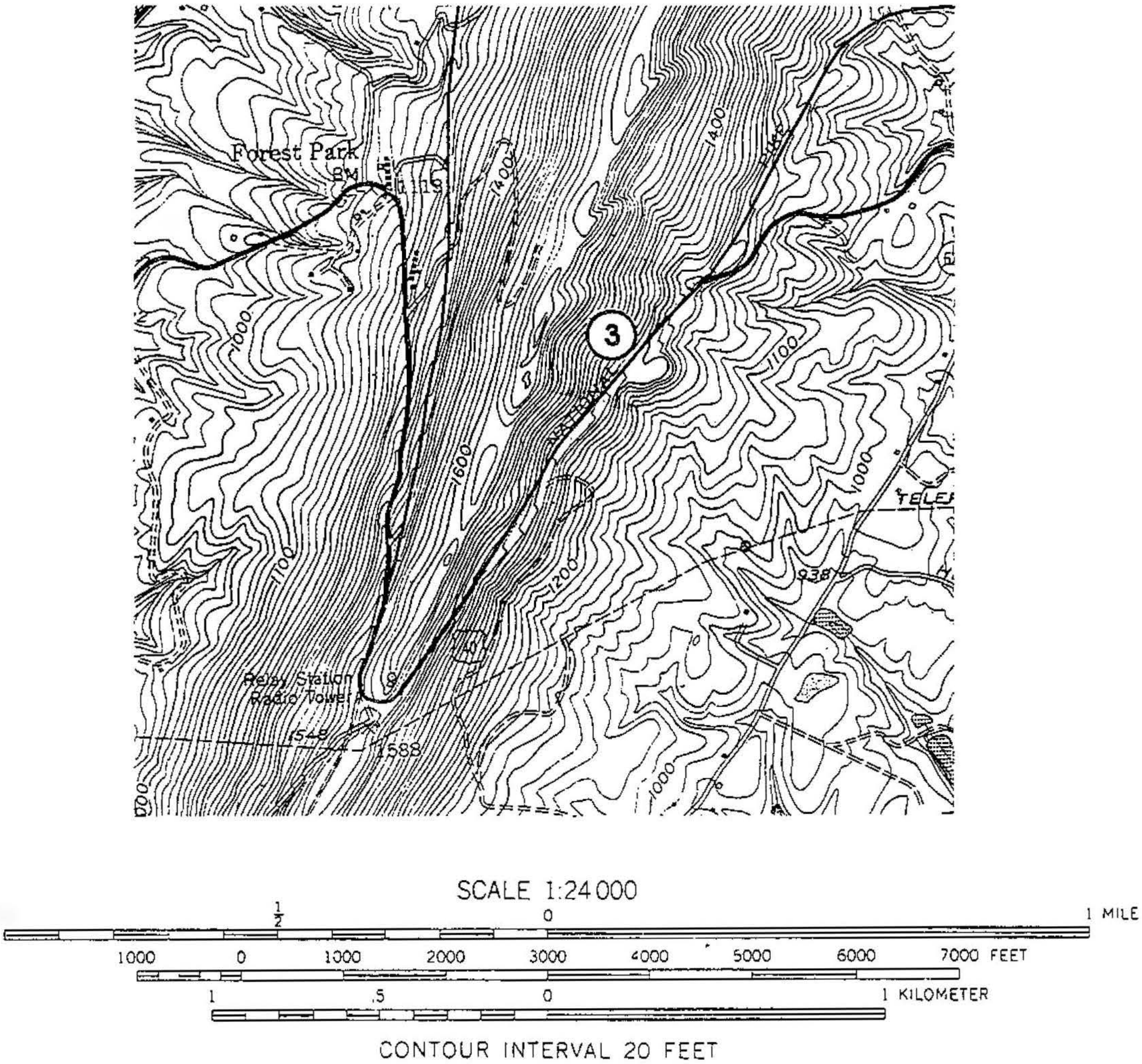
STOP # 3. Road cut, NW 1/4 Bellegrove quadrangle (Figure 8).

STOP 3 SIDELING HILL DIAMICTITE EXPOSURE

The outcrop here exposes a coarse-grained facies of the Lower Mississippian Rockwell Formation (Figure 6) that is not accessible at the Sideling Hill road cut 1.1 miles to the north (Stop # 2). Sevon (1979a) and (Suter 1991) refer to this lithified, unstratified, unsorted mixture of clay to boulder sized sediments containing clasts of a diverse range of lithologies as a polymictic diamictite. Sevon (1979a) has recognized a distinctive lithologic sequence associated with the diamictites. From bottom to top these are polymictic diamictite, pebbly mudstone, laminate, and sandstone.

At this outcrop, there is a diversity of clast compositions. The clasts make up on average 4% of the volume of the rock with a

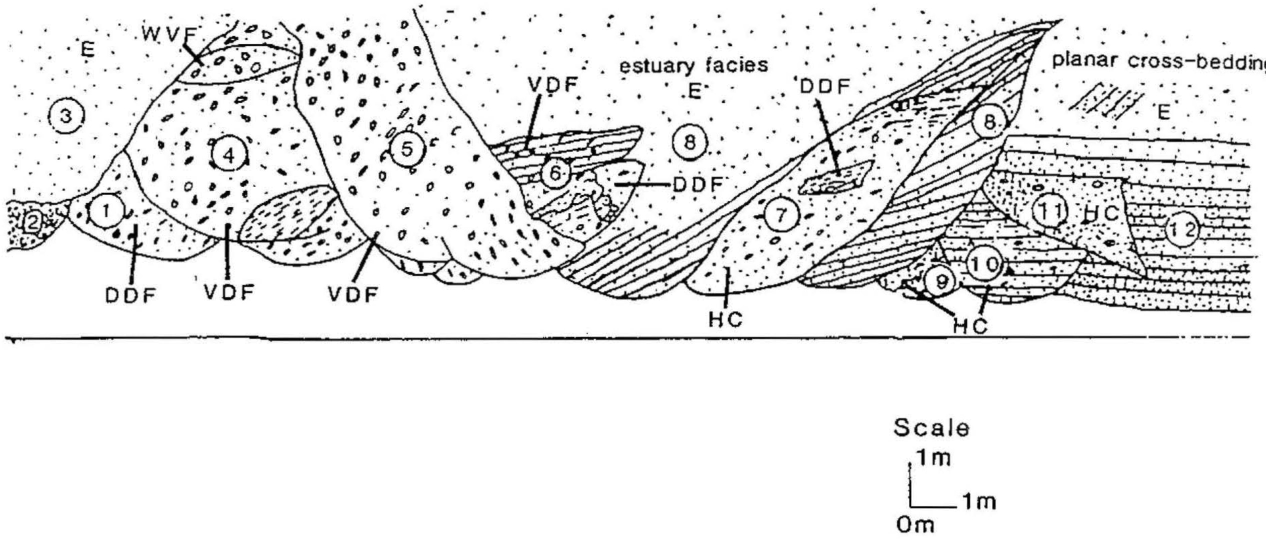
Figure 8. Location map for Stop # 3.



mean clast size of 18 mm (Suter 1991). The clasts consist of quartz, chert, phyllite, igneous rock (including volcanic fragments), sandstone, siltstone, as well as black and red shale (Suter 1991). Such diversity in the large clasts is common in this facies (Sevon 1969). Where and what was the source area for these clasts? Grain size distributions, isopach maps, and paleocurrent data indicate a southeastern source area (Pelletier 1958; Suter 1991).

What depositional environment produces this lithology? It has been interpreted as deltaic fluvial deposits (Pelletier 1958; Sevon 1969), subaqueous debris flow deposits (Sevon 1979a), and estuarine debris flow deposits (Suter 1991; Figure 9). The diamictites may mark the centers of sediment dispersal systems in a marginal alluvial plain environment extending from a highland source area to the southeast (Pelletier 1958; Sevon et al. 1978; Sevon 1979a,b). Suter (1991) suggests that these coarse-grained facies were deposited in a deltaic complex as the final stages of the Acadian Orogeny caused uplift to the east.

Figure 9. Sketch of outcrop at Stop # 3. E = estuary, VDF = viscous debris flow, DDF = dilute debris flow, WVF = waning viscous flow, and HC = hyperconcentrated flow (From Suter 1991, Fig. 18).



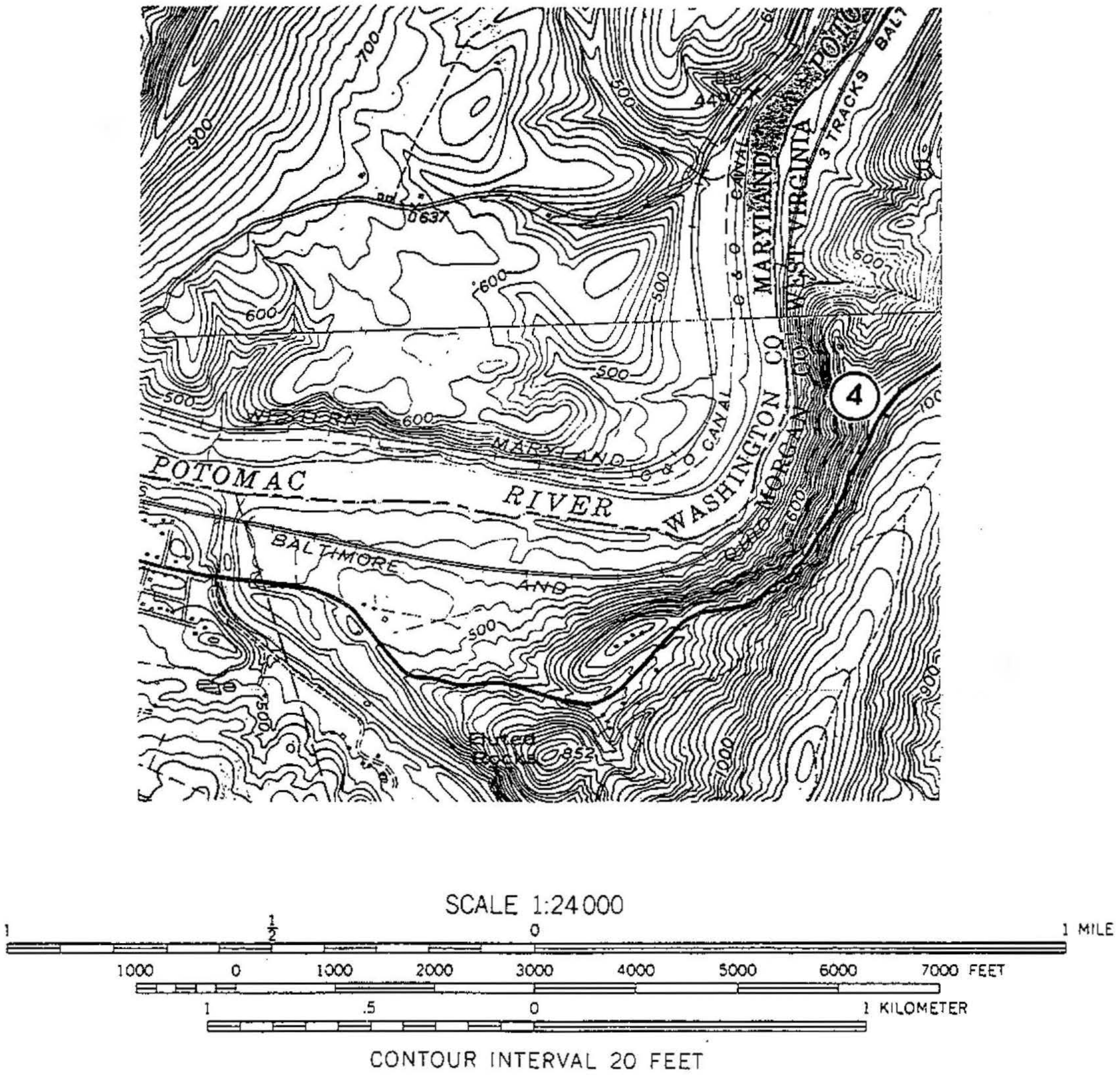
Also notable at this outcrop are the well-developed liesegang rings. These are made by the infiltration and precipitation of dissolved iron from the overlying red beds.

44.9	0.0	Continue downhill (east) on US Scenic route 40.
47.9	3.0	Turn left (north) at I-68 interchange. Immediately turn right (east) to get on I-68 east.
48.4	0.5	Exit # 77.
51.6	3.2	Exit right (exit # 82A) onto US Route 522 south toward Hancock, MD and Berkeley Springs, WV.
52.6	1.0	Exit for MD Route 144 in Hancock, MD.
53.1	0.5	Cross over Potomac River.
53.2	0.1	West Virginia state line.
53.3	0.1	Cross over Baltimore and Ohio Railroad.
53.4	0.1	Marcellus Formation outcrops in road cut on right (west). Route follows east limb of Cacapon Mountain anticlinorium which is held up by resistant Devonian Oriskany Sandstone.
55.5	2.1	US Silica glass plant on left (east) and quarry in Devonian Oriskany Sandstone on right (west). The Oriskany sand was used for the 200 inch (20 ton) Mt. Palomar reflecting telescope lens in California.
56.7	1.2	Devonian Oriskany Sandstone outcrops up hill to the right (west).
58.0	1.3	Turn right (west) at first stop light (Union Street) in Berkeley Springs, WV onto WV Route 9 toward Great Cacapon, WV.

58.2	0.2	Castle on right (west) presumably made of Devonian Oriskany Sandstone. The road goes up the east limb of the Cacapon Mountain anticlinorium.
58.7	0.5	At ridge crest, leave Devonian Oriskany Sandstone and enter Devonian Helderberg Formation. Valley between this ridge and next is occupied by the less resistant Silurian Rose Hill, Keefer, Rochester, and McKenzie Formations.
61.4	2.7	Pull off to the right at scenic overlook for Stop # 4.

STOP # 4. Overlook, SE 1/4 Bellegrove quadrangle and NE 1/4 Great Cacapon quadrangle (Figure 10).

Figure 10. Location map for Stop # 4.



STOP 4 CACAPON MOUNTAIN OVERLOOK

As stated in an historical marker at the site, National Geographic Magazine ranked this view as among America's outstanding "beauty spots." The view to the west looks stratigraphically up section across the Valley and Ridge physiographic province. The first ridge in the foreground (1.5 miles away), is the Tonoloway Ridge held up by the Devonian Oriskany Sandstone. The second and much larger ridge (4.5 miles away) is the Sideling Hill syncline (down strike from Stop # 2).

The Potomac River is visible directly below. The Cacapon River can be seen to the left (south) as it flows into the Potomac River just this side of the town of Great Cacapon, WV. A large entrenched bend in the Potomac River channel is visible below. It is covered by Quaternary alluvial terrace gravels up to the level of the barn in the center of the bend (Stose and Swartz 1912). These gravels (mapped as the Waynesboro soil series) have been interpreted as high terrace flood plain deposits of the Potomac River (Gilbert et al. 1959). At this site, they occur 220 feet above the current level of the river.

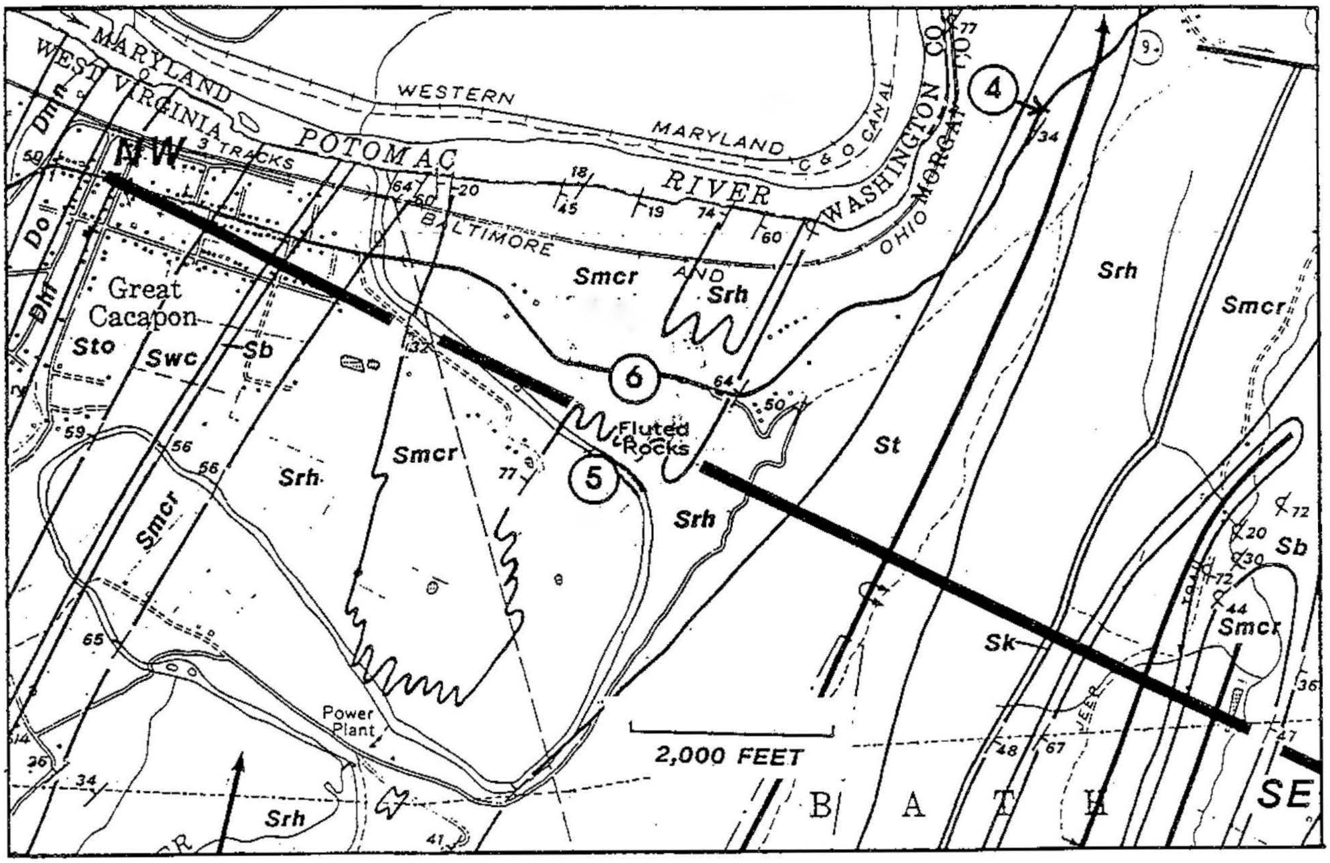
The overlook rests on the Lower Silurian Tuscarora Sandstone on the western flank of the Cacapon Mountain anticlinorium (Lessing et al. 1991; Figure 11). The Cacapon Mountain anticlinorium is asymmetrical like most folds in this region. The northwest limb is more steeply dipping (55^{o}) than the southeast ($35-45^{o}$) (Stose and Swartz 1912).

The Tuscarora Sandstone is visible across the road and immediately downhill. The Tuscarora here is a white, massive, well-cemented, resistant, mature, quartz arenite (Stose and Swartz 1912; Swartz 1923b; Cloos 1951a). As such, it is an important ridge-former in the area. Fossils are rare except for the trace fossils *Arthrophycus alleghaniensis*, *Arthrophycus harlani*, and *Skolithos verticali* (Stose and Swartz 1912; Swartz 1923b). Based on its lithology and fauna, this facies of the Tuscarora has been interpreted as a shallow marine beach environment (Cotter 1983). The geological marker at the overlook incorrectly places the Tuscarora Sandstone in the Clinton Group and incorrectly states that it forms the tightly folded sandstones in Fluted Rocks (Stops # 5 & 6). The Tuscarora Sandstone on Cacapon Mountain used to be mined for glass sand by the Silica Sand Company of Pittsburgh, PA (Stose and Swartz 1912).

61.4	0.0	Continue downhill (west) on WV Route 9 toward Great Cacapon, WV. The road goes down the west limb of the Cacapon Mountain anticlinorium.
61.8	0.4	Leave Silurian Tuscarora Sandstone and enter Silurian Rose Hill Formation.
63.1	1.3	Cross over Cacapon River and immediately turn left (south) onto unpaved road. Note the folded rocks of the Silurian Rose Hill Formation and Keefer Sandstone on the right (south).
63.8	0.7	Pull off road for Stop # 5.

STOP # 5. Overlook, NE 1/4 Great Cacapon quadrangle (Figure 12).

Figure 11. Geologic map for Stops 4-6. St = Tuscarora Sandstone, Srh = Rose Hill Formation, Sk = Keefer Sandstone, Smcr = McKenzie and Rochester Formations, Sb = Bloomsburg Formation, Swc = Wills Creek Shale, Sto = Tonoloway Limestone, Dhl = Helderberg Formation, Do = Oriskany Sandstone, and Dmn = Marcellus Formation (From Lessing et al. 1991).



STOP 5 FLUTED ROCKS OVERLOOK

This location is on the northwest limb of the Cacapon Mountain anticlinorium. The tightly folded rocks here expose the Rochester, Keefer, and Rose Hill formations (Prouty and Swartz 1923; Lessing 1987; Figure 11). These 3 units form the Silurian Clinton Group. The resistant beds revealing the intense folding belong to the Keefer Sandstone (Figure 13). Below is the older Rose Hill Formation which is squeezed into the cores of the anticlines. Above the Keefer Sandstone is the younger Rochester Shale which occurs in the cores of the synclines. The Rochester Shale is easily eroded and is not readily visible here. The age of the Keefer Sandstone and adjacent Rose Hill and Rochester formations is Middle Silurian based on a diverse ostracod, brachiopod, and trilobite fauna (Swartz 1923b; Amsden 1951).

All of the folds are essentially horizontal (i.e., do not plunge) and trend approximately N35°E (Lessing 1987). What produced these tight folds? Lessing et al. (1991) have proposed two models. The traditional view is that they formed from in response to forelimb thrust faults that served as a detachment

Figure 12. Location map for Stop # 5.

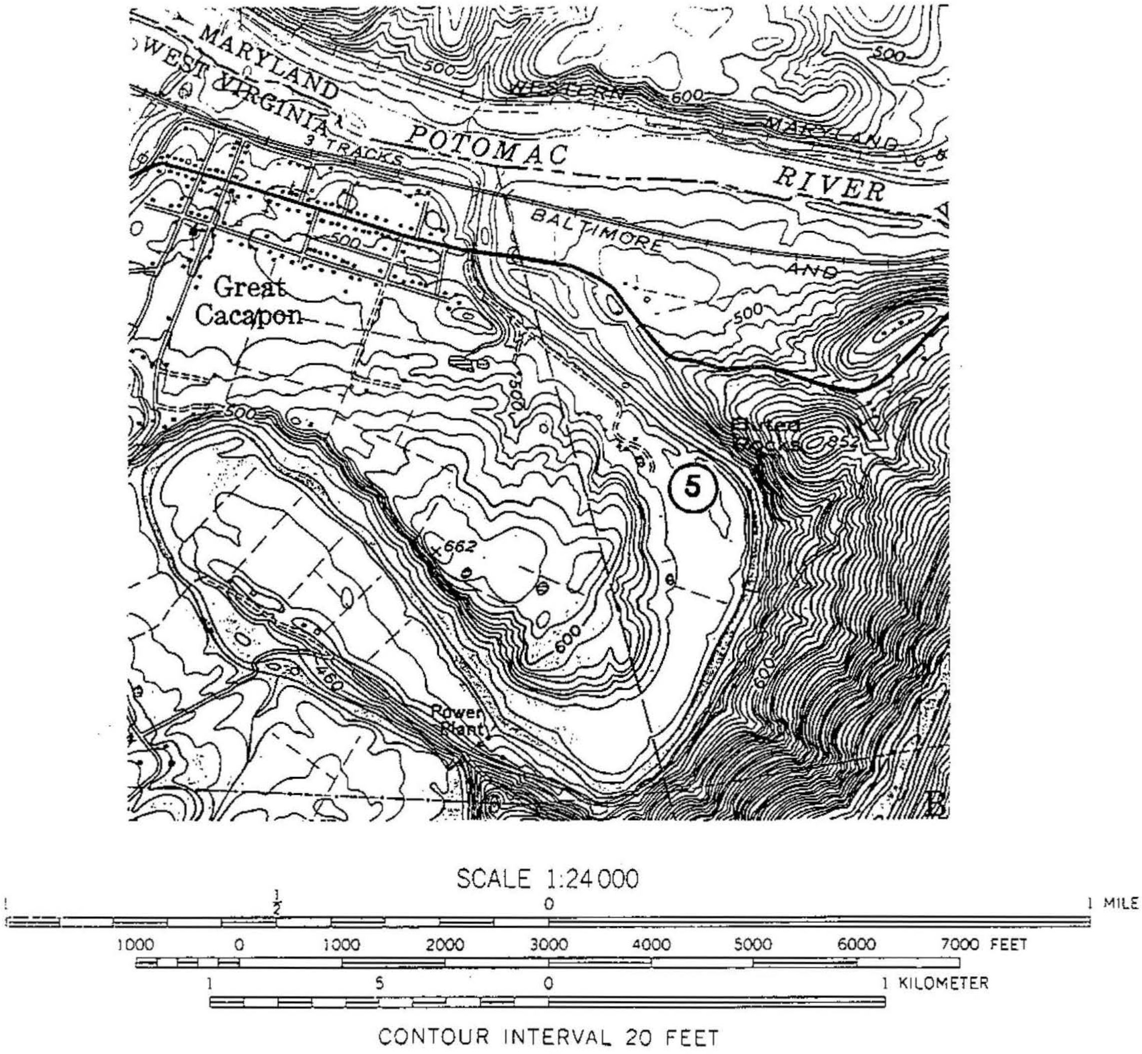
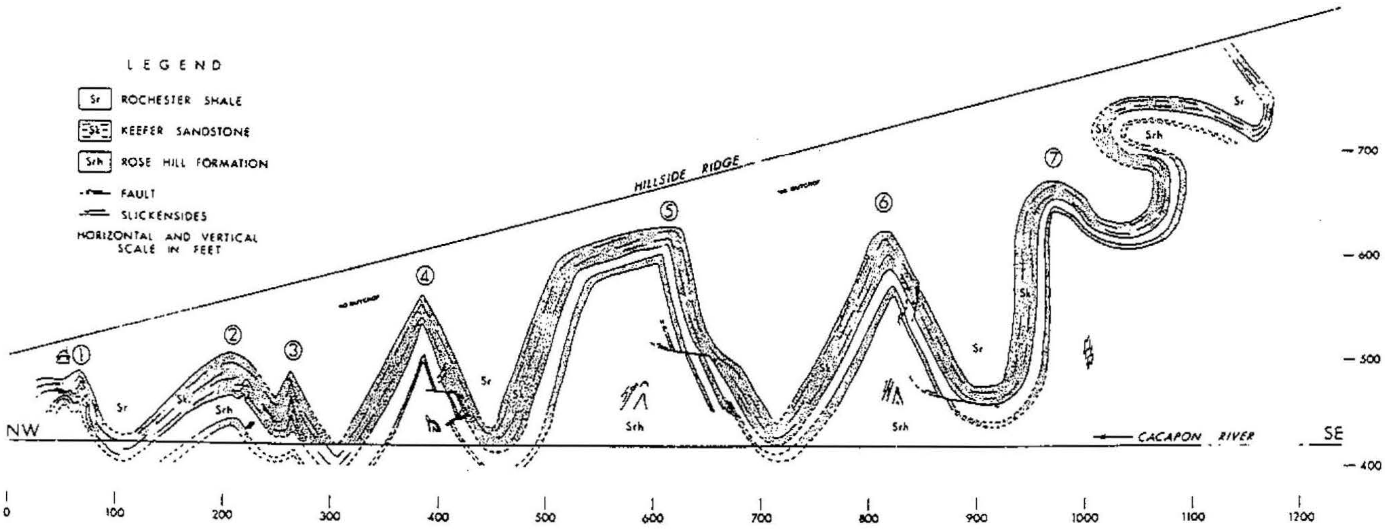


Figure 13. Sketch of outcrop at Stops # 5 & 6 (Modified from Lessing 1987).

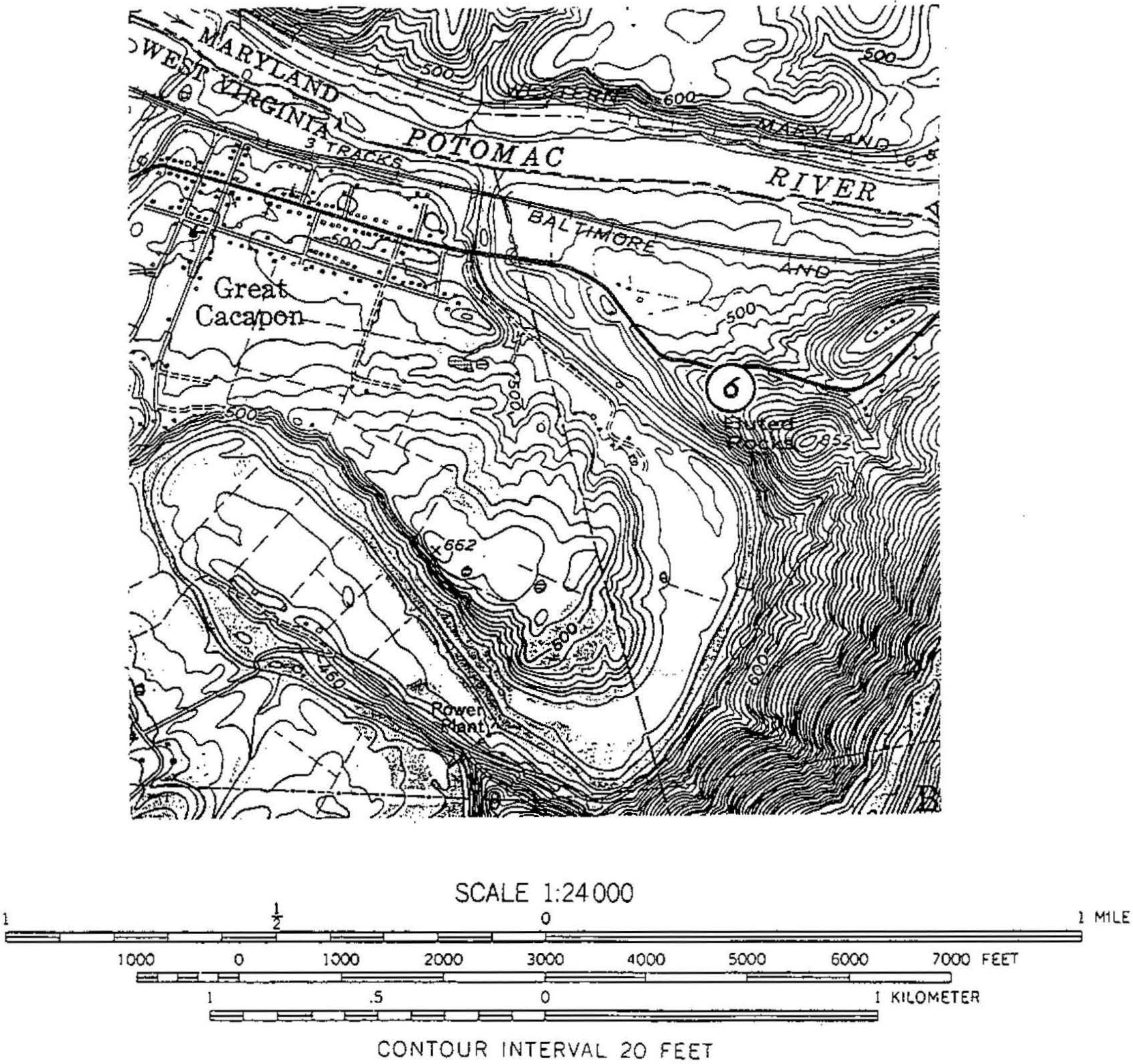


fault in the Rose Hill Formation (Lessing et al. 1991, Fig. 19B). The modern interpretation is that of a decollment in the underlying Rose Hill Formation (Lessing et al. 1991, Fig. 19A).

63.8	0.0	Return the way you came back to WV Route 9.
64.5	0.7	Turn right (east) onto WV Route 9 toward Berkeley Springs. Immediately cross over Cacapon River.
65.0	0.5	Turn right (south) onto abandoned unpaved road and park on road. Permission of land owner is required for access. Walk down road to abandoned house and proceed downhill (south) just past old house to Stop # 6.

STOP # 6. River cut, NE 1/4 Great Cacapon quadrangle (Figure 14).

Figure 14. Location map for Stop # 6.



STOP 6 FLUTED ROCKS

The Rose Hill Formation consists of olive colored shales with some thin-bedded sandy shales, and sandstones (Swartz 1923b). The Keefer Sandstone is a light gray, fine-grained quartzitic sandstone with occasional lenses of fossiliferous limestone and dark arenaceous shale (Swartz 1923b; Edwards 1978). Cross bedding is common. It contains linear trace fossil worm borrows of *Skolithos keeferi* oriented perpendicular to the bedding planes as well as the trace fossil *Arthrophycus* (Stose and Swartz 1912; Swartz 1923b). The Rochester Shale consists of light brown shale.

The lithology, sedimentary structures, and fauna of these units indicate a shallow marine shelf environment. The Rose Hill and Rochester formations represent slightly deeper water environments while the Keefer Sandstone represents a shallower beach facies.

The outcrop exposes seven paired anticlines and synclines that get larger from the northwest to the southeast (Figure 13). As approached from the northwest, the first three smaller folds are more accessible. Many of the folds exhibit flexural slip folding which means that deformation was accomplished by movement of individual layers past one another parallel to dip direction (like flexing a deck of cards). There are two pieces of evidence for this: 1) slickensides between the shale and sandstone beds indicate movement was between these beds, 2) undeformed (i.e., perpendicular to bedding) *Skolithos* worm tubes in the sandstones indicate movement was not within the sandstone beds.

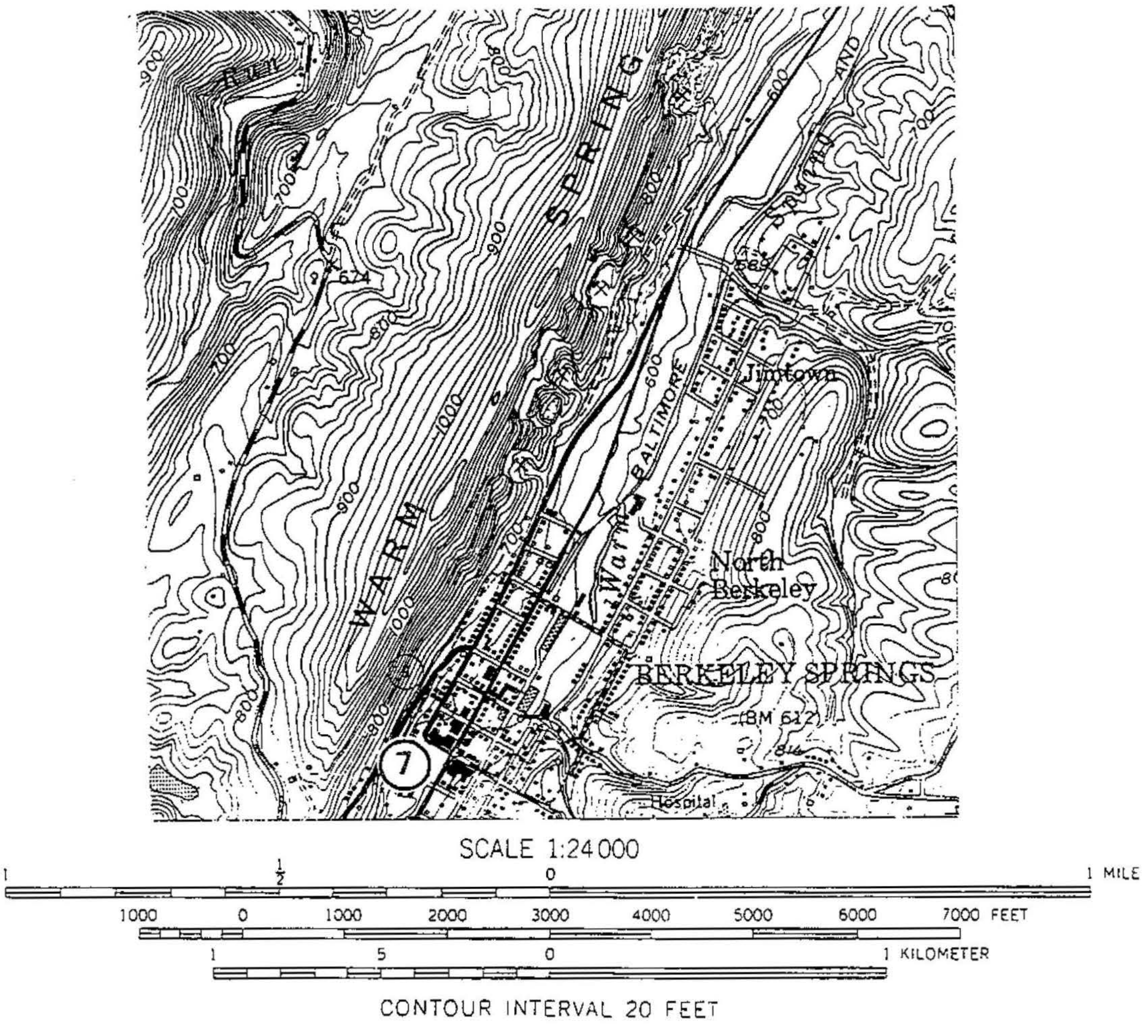
In the northwest limb of the second anticline, note the nice *Skolithos* and *Arthrophycus* trace fossils. In the northwest limb of the third anticline, note the ripple marks or small folds oriented perpendicular to the slickensides and parallel to the fold axis. These features may be small scale equivalents of the "megaripples" in the Cambrian Antietam Quartzite at the Mt. Cydonia quarry (Wilshusen and Sevon 1981, 1982). The common orientation of these features and the common occurrence of slickensides suggests these features may have a structural (i.e., not sedimentologic) origin.

For a more complete description of the exposures, see Lessing (1987).

65.0	0.0	Turn right (east) onto WV Route 9 and return the way you came back to Berkeley Springs, WV.
70.5	5.5	Turn right (south) at first stop light (US Route 522) in Berkeley Springs, WV.
70.8	0.3	Park on right at Berkeley Springs State Park for Stop # 7.

STOP # 7. State Park, SW 1/4 Hancock quadrangle (Figure 15).

Figure 15. Location map for Stop # 7.



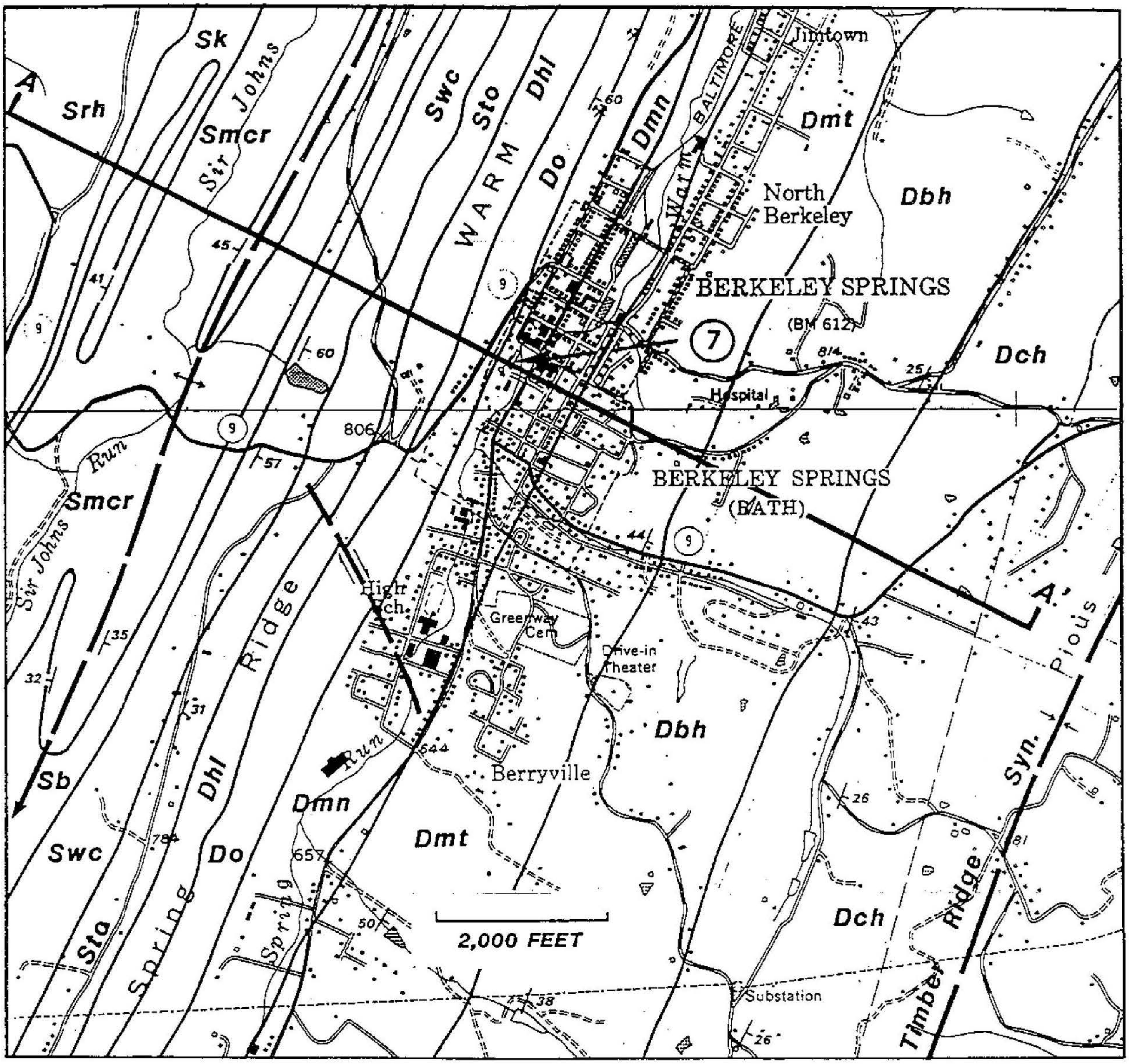
STOP 7 BERKELEY SPRINGS STATE PARK

This is mainly a rest stop before the drive back to Carlisle. If the gift shop is closed, Dawson's Market has beverages for sale and is located directly across US Route 522.

The thermal springs now located in Berkeley Springs State Park were once a famous, privately owned resort. George Washington, who originally surveyed this area, frequented the springs beginning in 1748. His "private hot tub" still exists on the grounds. The five main springs discharge 2,000 gallons of water per minute at a constant temperature of 74.3°F. The elevated temperature is due to deep circulation down the dip of the Devonian Oriskany Sandstone (Figure 16) where it is warmed by the geothermal gradient (Lessing et al. 1991).

70.8	0.0	Turn around and return the way you came back to Hancock, MD, north on US Route 522.
77.1	6.3	Exit right onto I-70 east toward Hagerstown, MD.
102.1	25.0	I-70 interchange with I-81 in Hagerstown, MD.

Figure 16. Geologic map for Stop # 7. Srh = Rose Hill Formation, Sk = Keefer Sandstone, Smcr = McKenzie and Rochester Formations, Sb = Bloomsburg Formation, Swc = Wills Creek Shale, Sto = Tonoloway Limestone, Dhl = Helderberg Formation, Do = Oriskany Sandstone, Dmn = Marcellus Formation, Dmt = Mahantango Formation, Dbh = Brallier and Harrell Formations, Dch = Chemung Formation (From Lessing et al. 1991).



ACKNOWLEDGMENTS

Many people made this trip possible. Ray Britcher initially proposed this area for a HAGS field trip. David Brezinski of the Maryland Geological Survey helped out tremendously with the Sideling Hill stops. Glenn Thompson and Wallace deWitt provided locality information for the Roundtop Hill and diamictite stops respectively. Mark Kauffman provided drafting services.

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