Maryland Department of Natural Resources
MARYLAND GEOLOGICAL SURVEY

GEOLOGIC GUIDEBOOK 6

CARBONATE RAMPS AND REEFS:
Paleozoic Stratigraphy and Paleontology of Western Maryland

June 8, 1996
Fieldtrip Guide Prepared for the North American Paleontological Convention VI
Sponsored by the Maryland Geological Survey

DEPARTMENT OF
NATURAL RESOURCES

MARYLAND GEOLOGICAL SURVEY

Established 1896

100th Anniversary
1896-1996

Part of the Maryland Geological Survey Centennial Celebration

1896-1996

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trip leader

Introduction

The purpose of this trip is to make a traverse through the Valley and Ridge Province of Maryland, and examine a number of the formations to illustrate the diversity of depositional environments and faunas present in the Lower and Middle Paleozoic rocks of the central Appalachians (Figure 1).

At the first stop we will examine the Middle Ordovician St. Paul Group and the overlying Chambersburg Limestone. These units record the transition from Middle Ordovician shallow ramp/platform environments to deep water ramp deposition at the onset of the Taconic orogeny. At the second stop you will be able to examine both ramp carbonates of the Upper Silurian-Lower Devonian Keyser Formation and the white, fossiliferous, beach/barrier bar sequence of the Ridgley Formation of the Oriskany Group. The third stop will be at the Sideling Hill Exhibit Center, which will also serve as a lunch stop. At this location you will see the Lower Mississippian foreland basin transition from marginal marine through meandering fluvial to braided fluvial deposition. The fourth stop will be near the village of Flintstone where we will examine a coral-stromatoporoid bioherm within the Silurian-Devonian Keyser Formation. Our last stop of the day will be a roadside examination of the Middle to Upper Silurian strata from the Rose Hill Formation through the base of the Tonoloway Formation.

Trip Westward

Mile 0 to 45

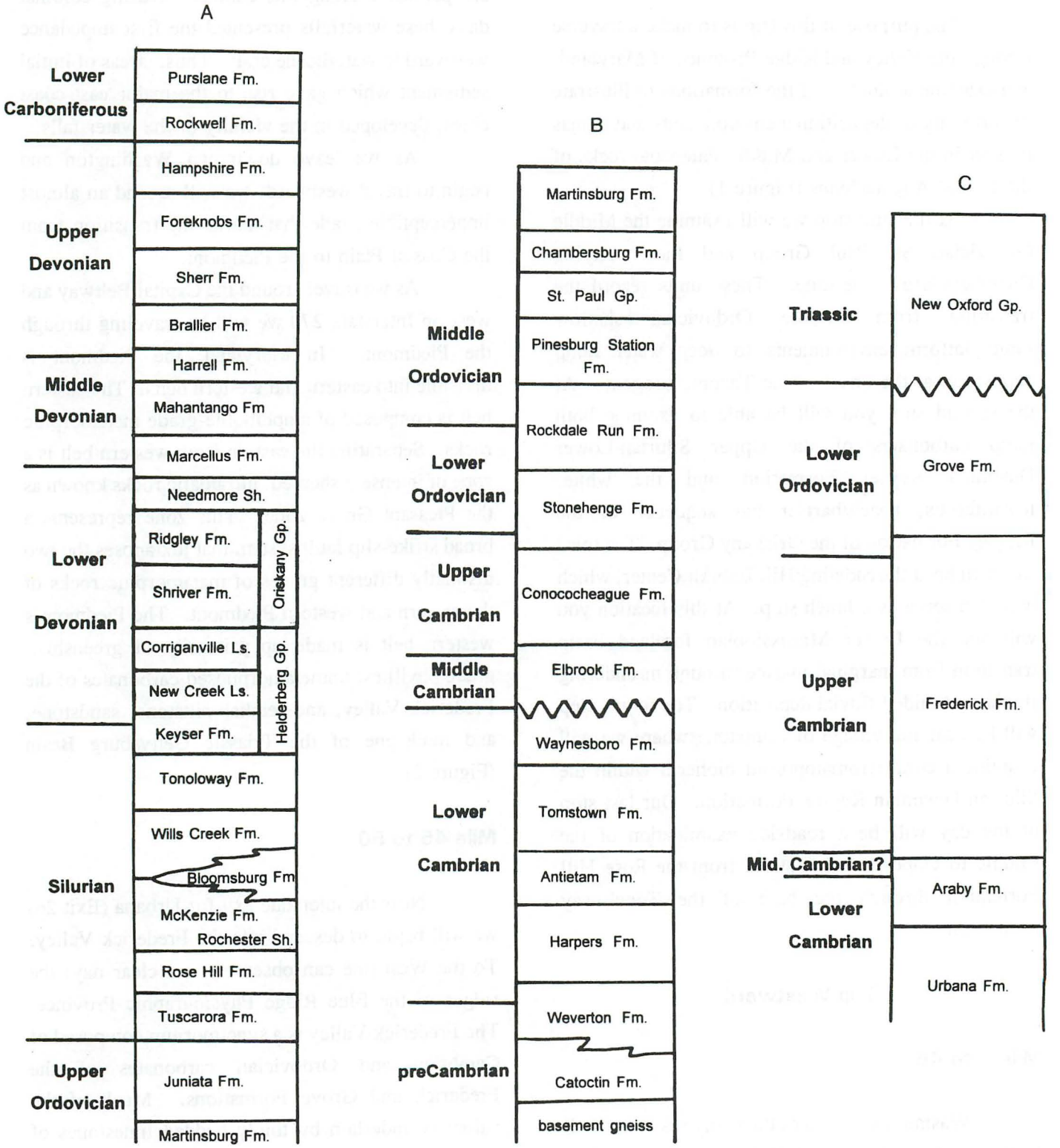
Washington is one of the many east coast Fall Line cities (e.g., Richmond, Baltimore, Philadelphia, and New York City) whose location is at the border between the Piedmont Physiographic Province to the west and the Coastal Plain to the east. Water falls are pervasive along this contact. During colonial days these waterfalls presented the first impedance westward to waterborne craft. Thus, areas of initial settlement which gave rise to the major east coast cities, developed in the vicinity of the water falls.

As we leave downtown Washington and begin to travel westward, we will ascend an almost imperceptible grade that marks the transition from the Coastal Plain to the Piedmont.

As we travel around the Capital Beltway and west on Interstate 270 we will be traveling through the Piedmont. In Maryland, the Piedmont is divisible into eastern and western belts. The eastern belt is composed of amphibolite-grade metamorphic rocks. Separating the eastern from western belt is a zone of intensely sheared, ultramafic rocks known as the Pleasant Grove zone. This zone represents a broad strike-slip fault system that juxtaposes the two distinctly different grades of metamorphic rocks of the eastern and western Piedmont. The Piedmont's western belt is made up primarily of greenshist-grade phyllites; unmetamorphosed carbonates of the Frederick Valley; and reddish siltstone, sandstone, and mudstone of the Triassic Gettysburg Basin (Figure 2).

Mile 45 to 50

Near the interstate exit for Urbana (Exit 26) we will begin to descend into the Frederick Valley. To the West one can observe (on a clear day) the ridges of the Blue Ridge Physiographic Province. The Frederick Valley is a synclinorium composed of Cambrian and Ordovician carbonates of the Frederick and Grove Formations. Much of the valley is underlain by thinly bedded limestones of the Upper Cambrian Frederick Formation. Reinhardt (1974) interpreted these limestones as representing offshelf and basinal deposits coeval to


A
Lower Carboniferous
Purslane Fm.
Rockwell Fm.
Hampshire Fm.
Upper Devonian
Foreknobs Fm.
Sherr Fm.
Brallier Fm.
Harrell Fm.
Middle Devonian
Mahantango Fm
Marcellus Fm.
Needmore Sh.
Lower Devonian
Ridgley Fm.
Shriver Fm.
Corriganville Ls.
New Creek Ls.
Keyser Fm.
Oriskany Gp.
Helderberg Gp.
Tonoloway Fm.
Wills Creek Fm.
Silurian
Bloomsburg Fm
McKenzie Fm.
Rochester Sh.
Rose Hill Fm.
Tuscarora Fm.
Upper Ordovician
Juniata Fm.
Martinsburg Fm.
B
Martinsburg Fm.
Chambersburg Fm.
St. Paul Gp.
Middle Ordovician
Pinesburg Station Fm.
Rockdale Run Fm.
Lower Ordovician
Stonehenge Fm.
Upper Cambrian
Conococheague Fm.
Middle Cambrian
Elbrook Fm.
Waynesboro Fm.
Lower Cambrian
Tomstown Fm.
Antietam Fm.
Harpers Fm.
Weverton Fm.
preCambrian
Catoctin Fm.
basement gneiss
C
Triassic
New Oxford Gp.
Lower Ordovician
Grove Fm.
Upper Cambrian
Frederick Fm.
Mid. Cambrian?
Araby Fm.
Lower Cambrian
Urbana Fm.

←←

Figure 1.— Paleozoic stratigraphy of Maryland that will be encountered during this trip. Column A is generalized stratigraphy of the Valley and Ridge Province of Maryland, excluding the Great Valley. Column B is generalized stratigraphy of the Great Valley section of the Valley and Ridge Province. Column C is the generalized stratigraphy of the Frederick Valley section the the Piedmont Province of Maryland.

the shallow-water platform deposits of the Conococheague Formation of the Great Valley to the west of the Blue Ridge. Apparently, the platform-edge deposits were removed by erosion when the Blue Ridge was uplifted. The synclinorium has at its core the Grove Formation, a Lower Ordovician unit composed of cyclic-bedded, shallow water limestone and dolomite. The contact between the two formations is interpreted as the transition from deep water ramp to shallow water platform deposition. The western border of the Frederick Valley is a large normal fault formed during the Triassic (Figure 3).

Miles 50 to 65

The Blue Ridge in Maryland is composed of a large anticlinorium (South Mountain anticlinorium) that is overturned to the west and cored by Precambrian basement gneissic rocks. The rocks that overlie the basement complex are Late Proterozoic basalts of the Catoctin Formation and Early Cambrian(?) metaquartizites and metagraywackes of the Weverton Formation (Figure 3). The ridges of the Blue Ridge are underlain by the resistant Weverton quartzites. As we begin a westward ascent from the Frederick Valley we will first cross the easternmost of the Weverton-formed ridges known as Catoctin Mountain. This ridge is the upright limb of the overturned South Mountain anticlinorium. Further to the west we will cross the overturned limb known as South Mountain.

Miles 65 to 82

Once we have descended from the western side of South Mountain we will enter the Great Valley section of the Valley and Ridge Physiographic Province where we will soon make our first stop. The Great Valley is a large synclinorium composed predominately of carbonate rocks ranging in age from Lower Cambrian through Middle Ordovician (Figure 3). This sequence of as much as 10,000 feet of carbonate rocks is almost entirely shallow water in origin. The center of the syclinorium is composed of clastic rocks of the Upper Ordovician Martinsburg Formation. Although no precise measurements of the Martinsburg exist for this region, it is estimated to be as much as 3,000 feet thick. The Martinsburg consists of silty shales at the base that become interbedded with flaggy sandstone and then thick-bedded sandstone at the top. This sequence represents the transition from flysch basin distal to proximal turbidites.

STOP 1

St. Paul Group-Chambersburg Limestone at Cedar Ridge Road and Interstate 70

Introduction

At this location we are on the western flank of the synclinorium, so that the strata are dipping to the east. The section here begins farther to the west within the Pinesburg Station Dolomite, the uppermost

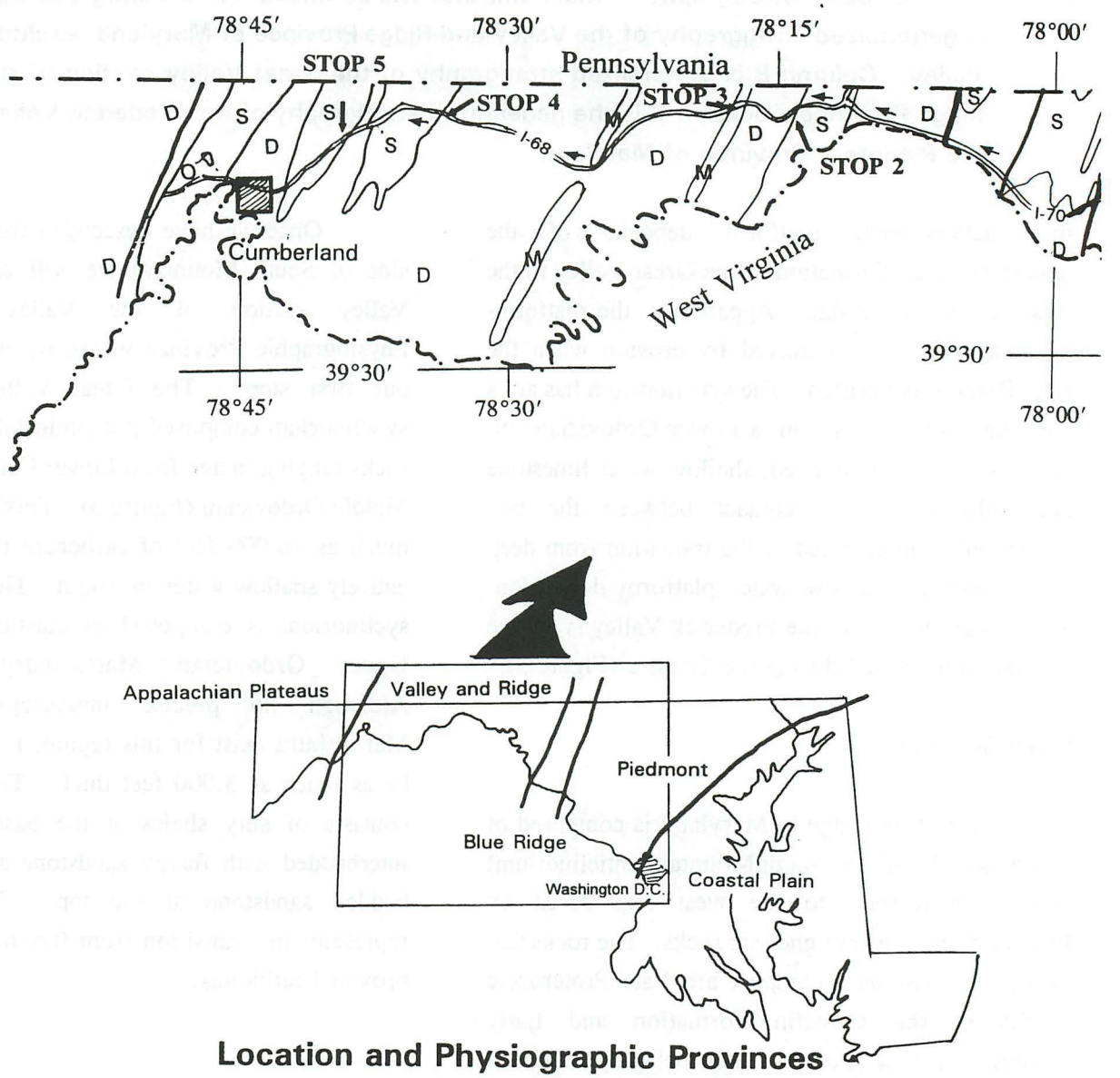
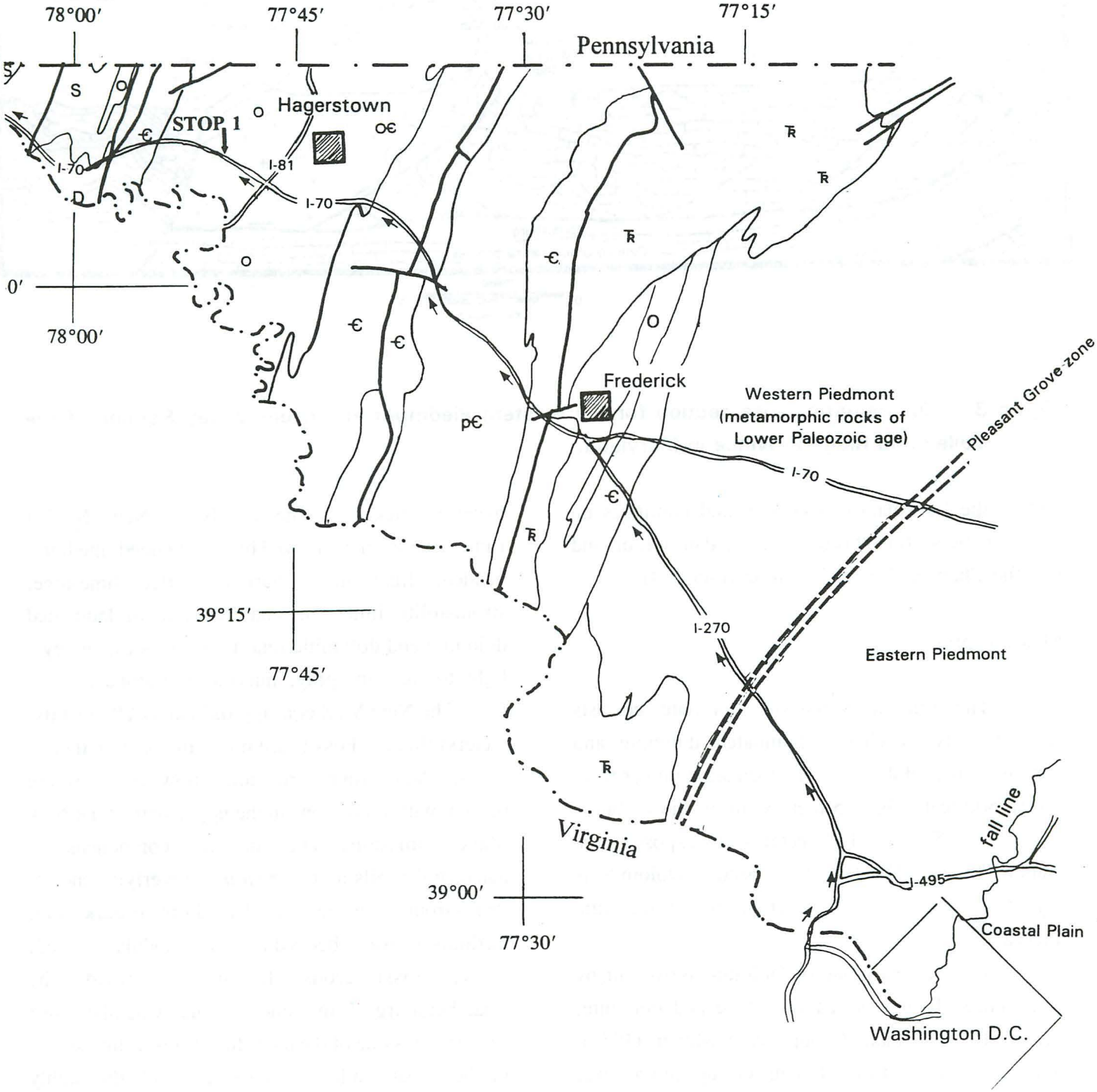


Figure 2.— Location map illustrating the geology, physiography and fieldtrip stop locations. Geology modified from Cleaves and others (1968).


78°00′
77°45′
77°30′
77°15′
Pennsylvania
Hagerstown
STOP 1
I-70
I-81
I-70
78°00′
Frederick
Western Piedmont
(metamorphic rocks of
Lower Paleozoic age)
Pleasant Grove zone
I-70
39°15′
77°45′
I-270
Eastern Piedmont
Virginia
fall line
I-495
39°00′
77°30′
Coastal Plain
Washington D.C.

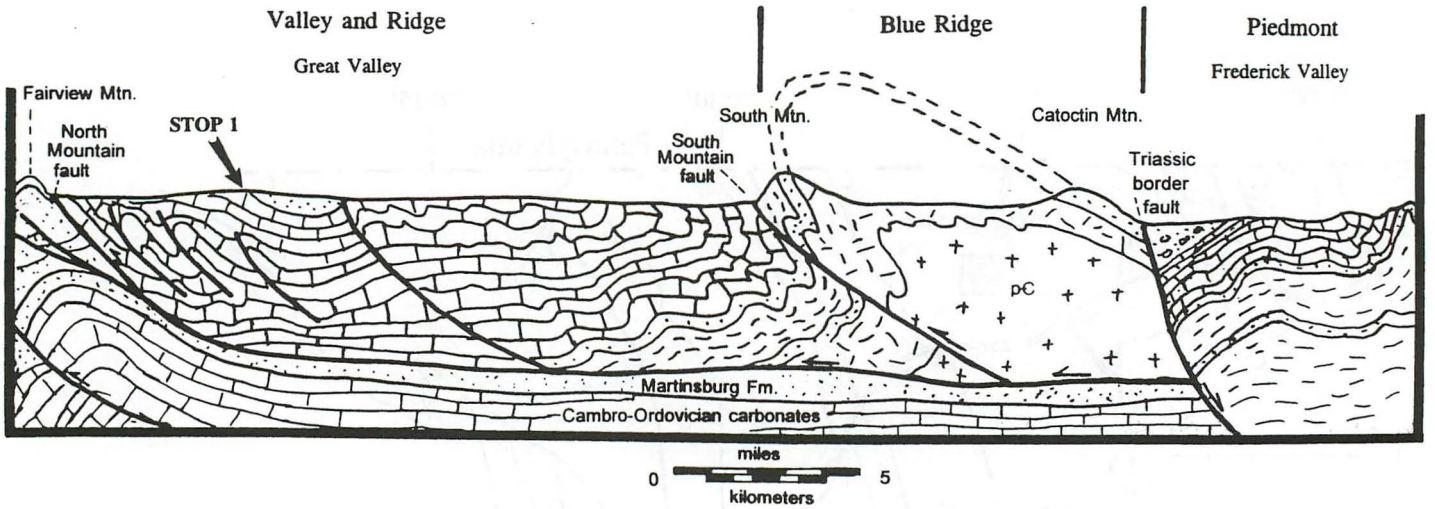


Figure 3.— Diagramatic cross section for the western Piedmont and Great Valley Section of the Valley and Ridge Province in Maryland.

unit of the Beekmantown Group, and continues up stratigraphic section through the St. Paul Group and into the Chambersburg Limestone (Figure 4).

Stratigraphy

The Pinesburg Station Dolomite consists predominately of cherty, laminated dolomite and burrow-mottled dolomite. The formation ranges from 400 to 500 feet (130-165 meters) in thickness, but only about 350 feet (120 meters) are exposed here (Sando, 1957). The Pinesburg Station Dolomite is unfossiliferous, save for numerous stromatolitic intervals.

The Pinesburg Station Dolomite is overlain by a sequence of interbedded limestone and dolomite, termed the St. Paul Group by Neuman (1951). Neuman subdivided the St. Paul Group into a lower formation, the Row Park Limestone, and an upper New Market Limestone (Figure 5A). The Row Park Limestone consists of light gray, massive, micritic to fenestral limestone with thin interbeds of laminated dolomitic limestone. It is approximately 250 feet (85 meters) thick. The overlying New Market Limestone is characterized by interbedded, medium-bedded, light gray, burrow-mottled limestone, stromatolitic limestone, and gray and tan, laminated dolomite and dolomitic limestone. It is capped by a light to medium gray, micritic limestone (Figure 5B). The New Market is approximately 200 feet (67 meters) thick. Fossils are not common in either of the St. Paul Group formations, however, they are present within horizons in the upper part of the New Market Limestone. The main faunal components are macluritid snails and *Tetradium*. Overlying the St. Paul Group is an interval of medium to dark gray, medium- to wavy bedded and even nodular-bedded, shaly, fossiliferous limestone termed the Chambersburg Limestone. The Chambersburg Limestone is one of the more fossiliferous limestones in the Great Valley of Maryland with the highly fossiliferous *Echinosphaerites* beds or interval near its base (Figure 5C).

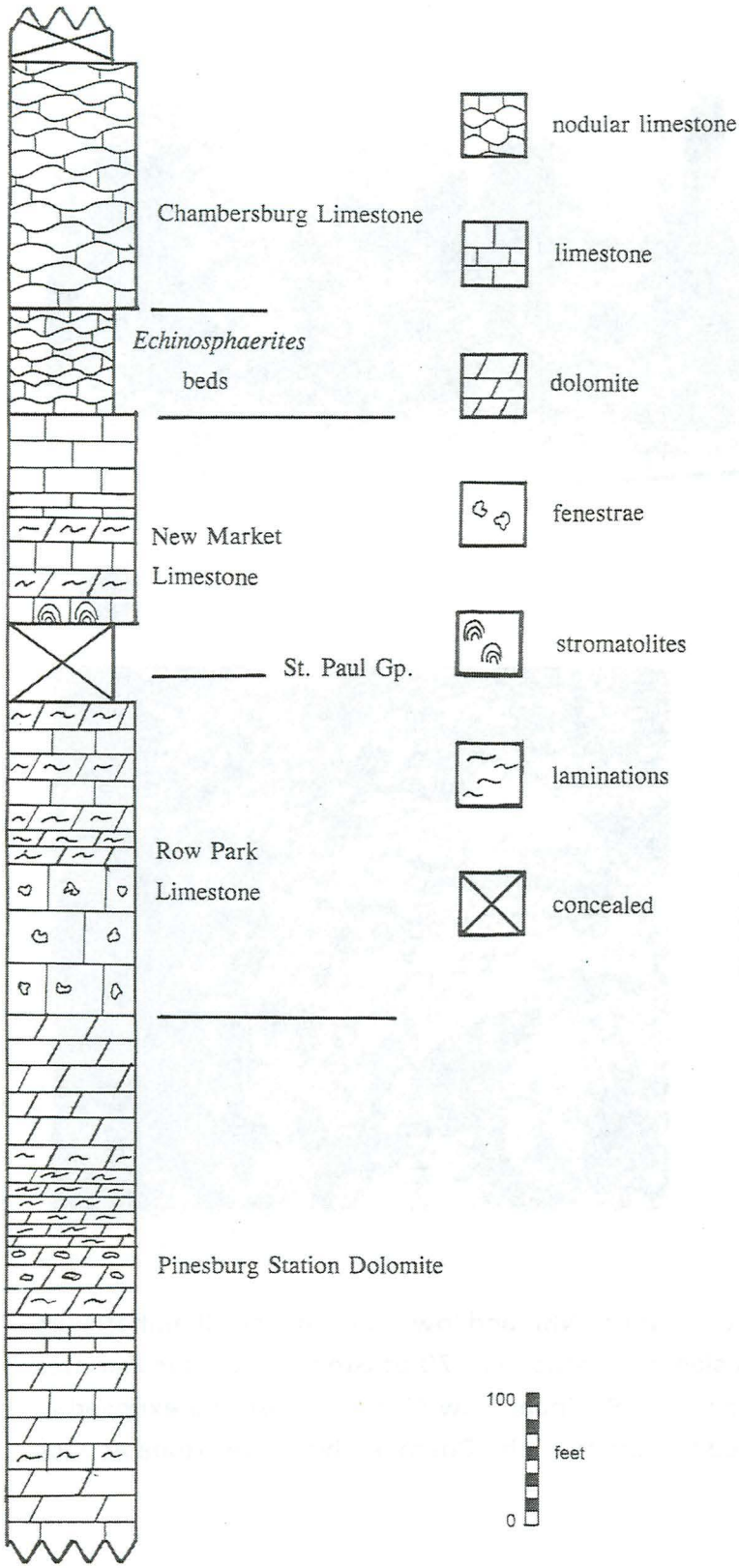


Figure 4. — Generalized stratigraphic section for Middle Ordovician section exposed at Stop 1.

Because the vertically juxtaposed lithologies are repeated throughout the St. Paul Group, Mitchell (1982, Table 2) suggested that the term Row Park be omitted and a terminology such as that currently utilized in Virginia be employed so that the entire St. Paul Group would be considered the New Market Limestone (Table 1).

Depositional Environments

Mitchell (1982) discussed in detail the vertical arrangement of lithologies within the St. Paul Group of Maryland. The lithotope characters are summarized in Table 1. The vertical arrangement of lithologies within the Pinesburg Station Dolomite to New Market Limestone led Mitchell to interpret the sequence as two separate transgressive and regressive pairs. See Table 1 for interpreted sea level curve.

The final deepening event that produced the Chambersburg Limestone resulted from the onset of downwarping that occurred during the Taconic orogeny. This deepening produced the graptolitic black shales of the overlying Martinsburg Formation (not seen at this stop).

Collecting

Although numerous intervals within this section are fossiliferous, those individuals interested in collecting are directed to the *Echinosphaerites* beds (dark gray shaly) near the base of the Chambersburg Limestone. These beds get their name from the abundant remains of the cystoid *Echinosphaerites*. Also common within this interval are trilobites (*Isotelus, Bumastus, Calliops*), brachiopods, bryozoans, and corals.

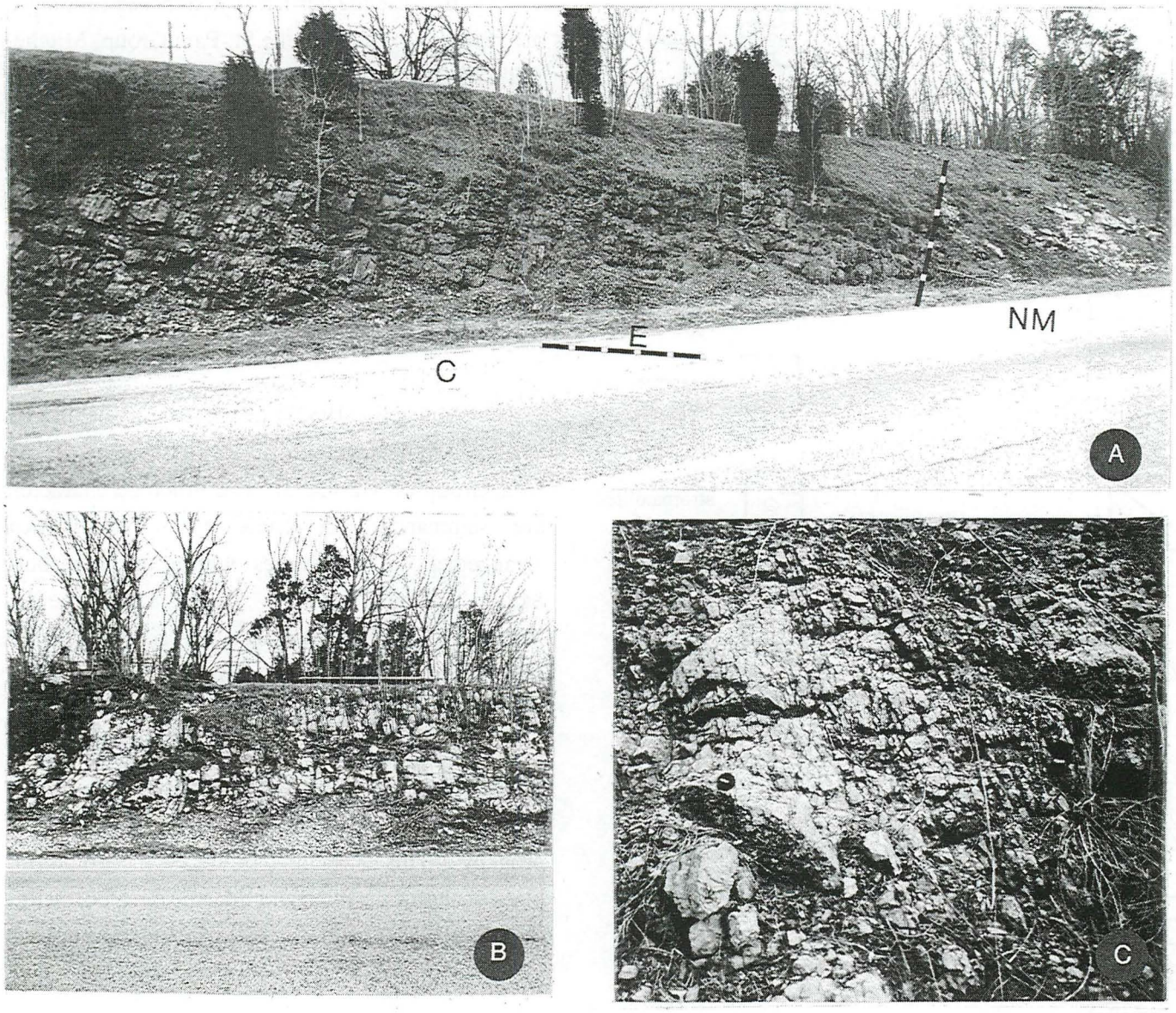


Figure 5. — A, Upper part of the New Market Limestone (NM) and lower part of the Chambersburg Limestone (C) exposed along the south side of westbound I-70 at Stop 1. *Echinosphaerites* beds exposed in the center of the photograph. B, Upper New Market Limestone exposed at Stop 1. C, Characteristic nodular-bedded limestone of the Chambersburg Limestone at Stop 1.

Miles 82 to 106

As we proceed westward from Stop 1 we will cross the western limb of the Great Valley (i.e., Massanutten) synclinorium. Straight ahead is Fairview Mountain, composed of the Lower Silurian Tuscarora Sandstone. At the eastern base of the mountain is a large thrust fault known as the North Mountain fault that places Middle Cambrian carbonates of the Elbrook Formation upon the Upper

Neuman, 1951	Mitchell, 1982	lithology	environment	sea level deeper →→
Chambersburg Fm.	Chambersburg Fm.	nodular-bedded, shaly limestone	deeper subtidal ramp	
New Market Fm.	Chambersburg Fm.	fossiliferous lime mudstone	shallow subtidal shelf	
New Market Fm.	Loysburg Fm.	cyclic laminites	restricted tidal flat	
New Market Fm.	Loysburg Fm.	stromatolitic cycles	open circu-lation tidal flat	
Row Park Fm.	Lincolnshire Fm.	cyclic laminites	restricted tidal flat	
Row Park Fm.	New Market Fm.	fenestral lime mudstone	tidal pond	
Beekmantown Fm.	Pinesburg Station Fm.	dolomitic cycles	restricted tidal flat	

Table 1.— Relationships between stratigraphic nomenclature, lithology, depositional environments and sea level curve at Stop 1.

Ordovician and Silurian clastics of the western Valley and Ridge Physiographic Province (Figure 3). Once we have passed the Clear Spring exit (Exit 18) we will cross this fault and begin to travel parallel to the Potomac River. For the next ten miles we will continue westward, driving for the most part on gravel terraces of the Potomac River. Most of the ridges to the north and south are composed of Late Devonian clastic rocks of the Greenland Gap Group and Hampshire Formation. Exiting I-70 at Hancock, we will continue westward on I-68 to the Woodmont Road exit (Exit 77). Turn east on Maryland Route 144 for less than a mile, then onto Sandy Mile Road.

STOP 2

U.S. Silica property along Sandy Mile Road

Introduction

At this stop there are two formations to examine. The lower, the Silurian-Devonian Keyser Formation, occurs in an abandoned quarry just to the east of Sandy Mile Road. The main focus of this stop is the Lower Devonian Ridgley Sandstone. This somewhat resistant unit forms Tonoloway Ridge to the south and accounts for the name *Sandy Mile* Road.

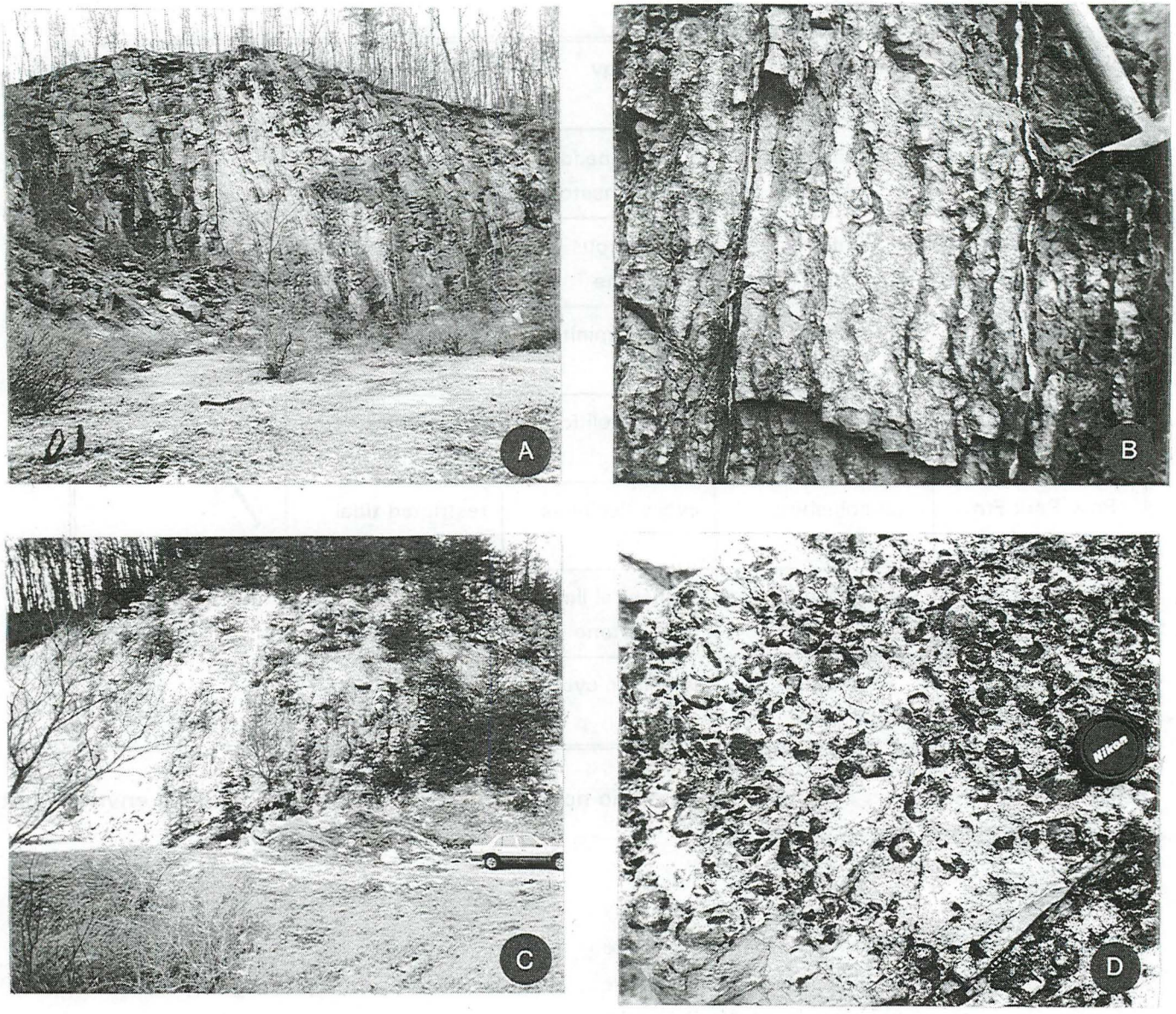


Figure 6.— A, abandoned quarry within the Keyser Formation at Stop 2. B, Nodular-bedded lime wackestone characteristic of the open shelf facies of the Keyser Formation of Western Maryland. C, White, friable, carbonate cemented sandstone of the Ridgley Formation exposed along Sandy Mile Road, at Stop 2. D, Molds of brachiopods and gastropods on a bedding surface within the upper Ridgley Formation.

Stratigraphy

The Keyser Formation

Approximately 200 feet (65 meters) of the Keyser Formation, the basal unit of the Helderberg Group, is exposed in the abandoned quarry located east of the road (Figure 6A). At this location nearly the entire Keyser Formation is composed of nodular-bedded, argillaceous, fossiliferous lime wackestone (Figure 6B). This interval is essentially devoid of either packstone or grainstone intervals. The uppermost 30 feet (10 meters) becomes more regularly bedded and contains a few thin layers (6-12 inches, 15-30 cm) of grainstone-packstone. The lithologies exposed here are included within the nodular facies of Head (1969) and the shaly/nodular-bedded/cherty limestone facies of Dorobek and Read (1986).

Although these rocks are highly fossiliferous, most faunal components have been comminuted to fragmental stages. The most common faunal components include abundant ramose bryozoans, rugose corals, tabulate corals, trilobites, brachiopods, and crinozoans. A few intervals near the top of the exposure contain coquinas of brachiopod valves and indications of small-scale hummocky cross-stratification.

Based on conodont ranges, the Silurian/Devonian contact can be placed within the upper Keyser near the contact with the overlying New Creek Limestone (Denkler and Harris, 1988). Consequently, the Keyser Formation here is almost totally Silurian (Pridolian) in age.

Between the Keyser exposure and the outcrop of the overlying Ridgley Sandstone farther along the road is a covered interval approximately 70 feet (25 meters) thick. It is assumed that this covered interval contains the typical intervening units of the Corriganville Limestone, Mandata Shale, and Shriver Chert.

Ridgely Sandstone

The Ridgley Sandstone is the upper formation (overlying the Shriver Chert) of the Oriskany Group. The Ridgley Sandstone at this location is approximately 150 feet (50 meters) thick (Figure 6C). It consist of very light gray, medium-bedded, fine- to medium-grained, carbonate cemented, quartz sandstone. Cross-bedding is prevalent in only a few intervals. This unit is mined to the south in West Virginia by U.S. Silica, mainly as a glass sand. As a consequence of the carbonate cementation, this sandstone is easily leached on exposed surfaces, leaving behind a residue of pure quartz sand.

The Ridgley Sandstone is highly fossiliferous in some intervals. These fossiliferous intervals are concentrated near the top of the formation and are in the form of internal and external molds (Figure 6D). The faunal components are primarily large, thick-shelled, coarsely plicate brachiopods, and more rarely large, platyceratid gastropods. These coarsely plicate brachiopods are indicative of turbulent, current-swept environments. The preponderance of brachiopod valves are disarticulated and convex-up; this indicates that they have been rearranged post-mortem by traction currents.

Depositional Environments

The Keyser Formation has been examined from a regional perspective by Dorobek and Read (1986). They interpreted the nodular-bedded limestone that characterizes the Keyser at this location as having been deposited in a relatively deep-water ramp environment. Primarily, the burrowed character of the sediments and the lack of current features (e.g. cross-bedding, graded-bedding)

suggested to Dorobek and Read that these rocks were deposited below fair-weather wave base. They estimated water depths of 75 to 150 feet (25-50 meters). Head (1969) interpreted these lithologies as occurring near the center of the Keyser seaway.

Conversely, the Ridgley Sandstone at this location appears to have been deposited within a very shallow water environment. The presence of cross-bedding, coarsely plicate and thick-shelled brachiopods, and the disarticulated, convex-up brachiopod valves suggest strong, current-swept conditions. Perhaps a beach/barrier bar complex of environments is compatible with the indicators discussed above.

Collecting

Fossil collection at this stop is largely restricted to the Keyser Formation. Although most of the fossils are in the form of fragments, complete brachiopods, bryozoans, and corals can be found. The best collecting is from slabs and blocks that have fallen from the highwall. Furthermore, the upper strata of the Ridgley Sandstone provide some excellent molds of brachiopods and platyceratid gastropods.

Mile 106 to 109

Returning to I-68, we will continue westward, climbing the eastern flank of Sideling Hill. As we do, we will be passing through Middle and Upper Devonian clastic rocks. At the summit of Sideling Hill, exit I-68 to the exhibit center.

STOP 3

Sideling Hill

Introduction

This location will serve both as Stop 3 and our lunch stop. Depending on the availability of hardhats and permission form the Maryland State Highway Administration we may or may not be able to hike to the western side of the syncline to examine the diamictite and marine shale within the lower Rockwell Formation. Please feel free to walk through the visitor center to look at the exhibits.

Stratigraphy

The road cut through Sideling Hill exposes the Lower Mississippian Rockwell and Purslane Formations (Figure 7). The Rockwell Formation, the lower of the two units, extends from the lowestmost strata exposed up to the base of the first thick sandstone unit. The Purslane Formation is mainly composed of sandstone; its resistance to erosion is the main reason for the topographic prominence of Sideling Hill.

The Rockwell Formation consists of interbedded sandstone, siltstone, and shale and at this exposure possesses a diamictite at its base. This basal diamictite is an unsorted mass, containing clasts ranging in size from mud through boulders. Some of the larger cobbles and boulders are composed of granite, chert, and graywacke. Overlying the diamictite is an interval, 30 feet (10 meters) thick, of herringbone cross-bedded, medium-grained, well-sorted sandstone that appears to be tidal in origin (Bjerstedt and Kammer, 1988; Brezinski, 1989b). Upsection from the herringbone cross-beddded sandstone is a 100-foot (30 meters) interval of interbedded sandstone and siltstone with thin coalbeds and some marine fossils. This interval has been correlated with the Riddlesburg Shale of central Pennsylvania, a very early Mississippian marine transgression equivalent to the Bedford Shale of Ohio (Bjerstedt, 1986; Bjerstedt and Kammer, 1988; Brezinski, 1989a). Scarce

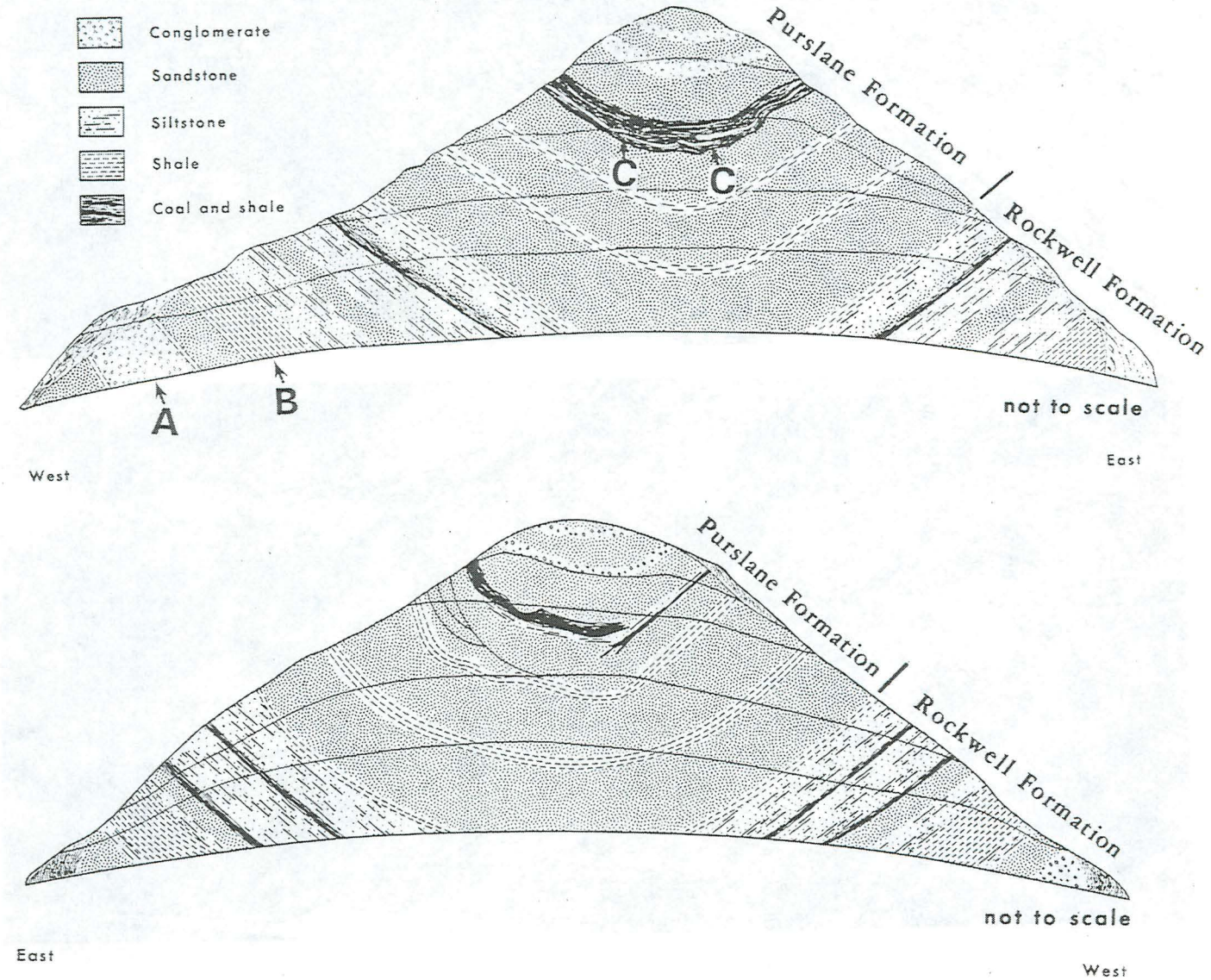


Figure 7.— Sketch cross sections of the north (top) and south (bottom) sides of the exposure at Stop 3, Sideling Hill, Maryland.

fossils from this interval include lingulid brachiopods; the articulate brachiopods, *Rugosochonetes*, *Macropotamorhyncus*, and *Schuchertella;* and indeterminate bivalves (Brezinski, 1989b).

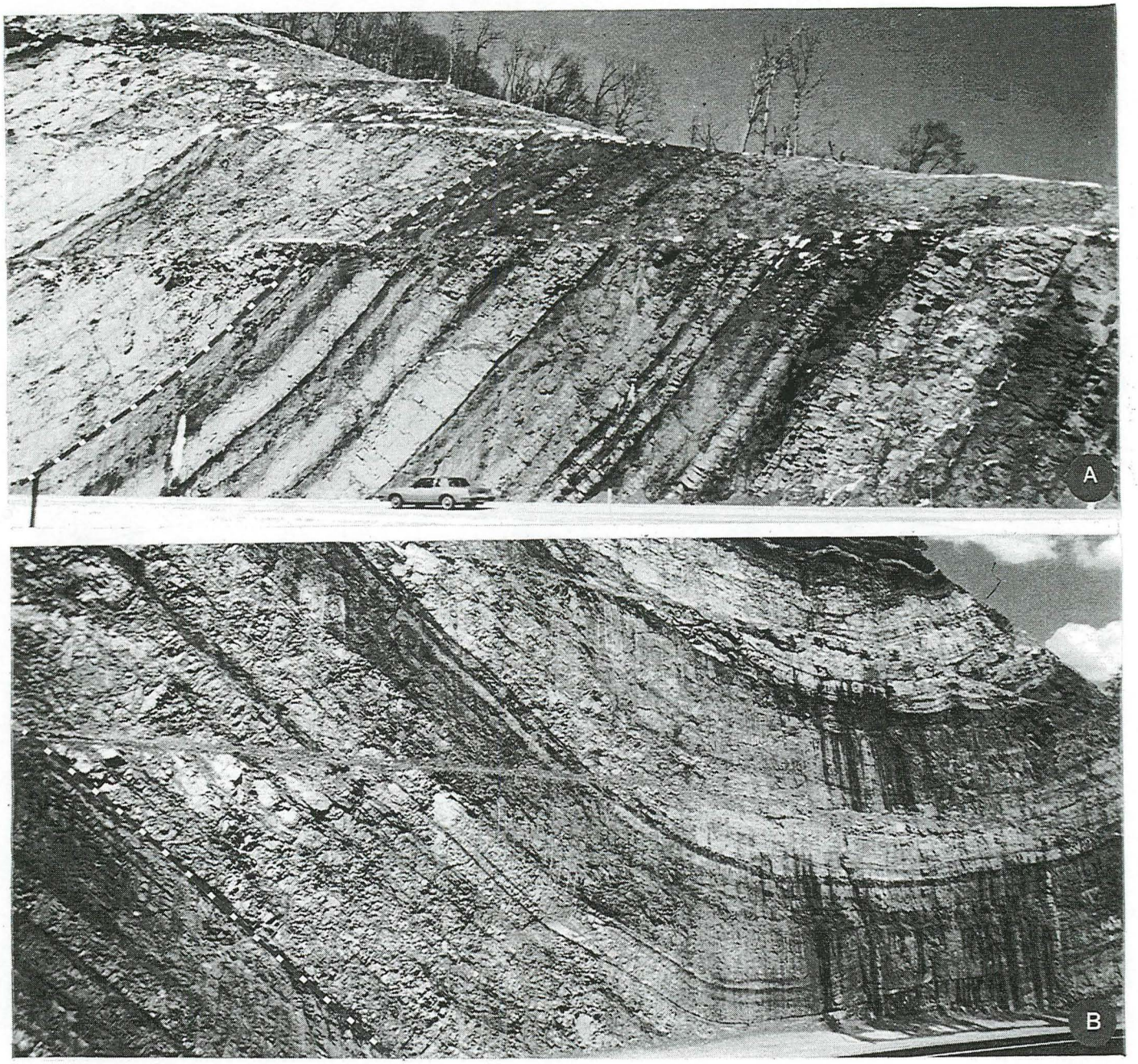


Figure 8.— A, Exposure of the upper Rockwell and basal Purslane Formations along the westbound lanes of I-68 at Stop 3, Sideling Hill. Rockwell/Purslane contact at dashed line. Note thin, sharp-based sandstone units (light colored) near the top of the Rockwell Formation. B, Thick, fluvial sandstones of the Purslane Formation at Stop 3. Contact with the underlying Rockwell Formation at lower left of photograph (dashed line).

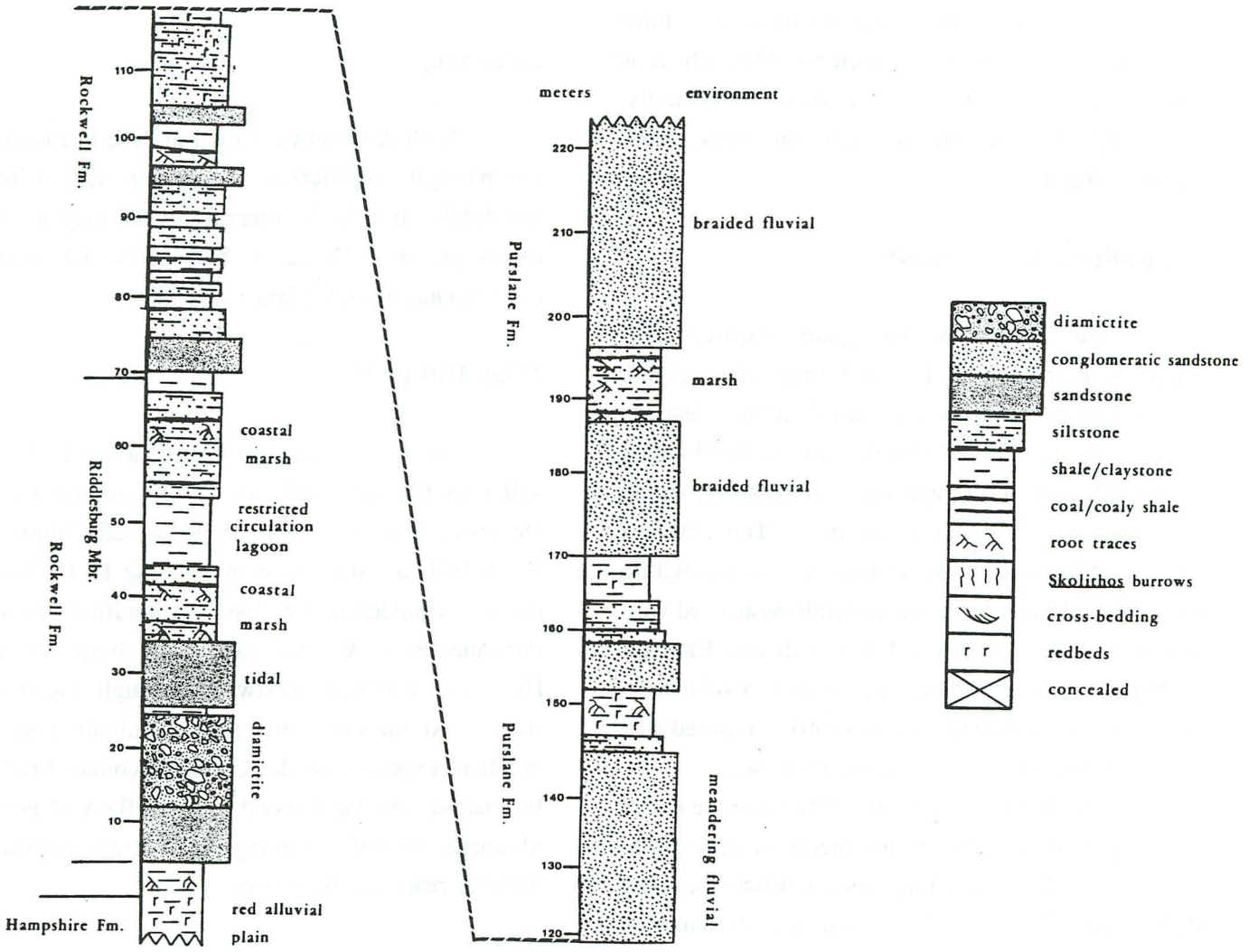


Figure 9.— Stratigraphic section exposed at Stop 3 and interpreted depositional environments (modified from Brezinski, 1989a)

Overlying the Riddlesburg Shale interval is the upper 120 feet (40 meters) of the Rockwell Formation. This interval contains interbedded channel-phase sandstones, 10 to 30 feet (3 to 10 meters) thick, and reddish-brown, root-mottled siltstone and mudstone (Figure 8A).

The base of the Purslane Formation is marked by the lowest thick (> 50 feet, 15 meters) sandstone in the section. At this location, the lowest Purslane unit is a 75-foot (25 meters) thick medium-grained, sandstone exhibiting epsilon cross-bedding and basal lag gravels. This unit is overlain by a thin interval (20 feet, 7 meters) of root-mottled, reddish mudstone and then another 45 feet (15 meters) thick,

cross-bedded sandstone unit. Overlying this second sandstone unit is an interval of interbedded coaly shale and thin coal. The ridge is capped by a third sandstone unit 90 feet (30 meters) thick which is much coarser-grained than either of the lower units. This capping sandstone contains numerous cross-bedded conglomeratic intervals.

Depositional Environments

The Lower Mississippian Sideling Hill sequence represents a foreland prograding clastic wedge that progressively replaced marine deposits with coastal plain, meandering fluvial, and braided fluvial deposits. There are many questions regarding the origin of the basal diamictite. The unsorted character plus the fact that similar occurrences within the Rockwell Formation are invaribly associated with tidal sandstone deposits led Bjerstedt and Kammer (1988) to propose that the diamictite is a submarine slide deposit. Likewise, Suter (1991) proposed that it is the result of an estuarine debris flow.

The strata overlying the diamictite are easier to interpret as to their environments of deposition. The tidal sandstone grading upsection into the coaly shales and siltstone and subsequently into marine strata of the Riddlesburg Shale indicate a transgressive sequence from beach/coastal to marsh/restricted circulation marine (Figure 9). Upsection from the marine interval, regressive facies are indicated by a return to the tidal marsh and then fluvial plain deposits (channel sandstone and root-mottled mudstone).

The thick, channel-phase sandstones with epsilon cross-bedding and thin overbank deposits of the lower Purslane Formation indicate a channel-dominated, meandering fluvial environment. The coarser conglomeratic deposits in the upper part of the formation may indicate that gradients increased and environments changed from a meandering fluvial to braided fluvial facies near the end of Purslane deposition.

Collecting

Both the Rockwell and Purslane Formations are sparingly fossiliferous. The marine faunas from the Riddlesburg Shale interval are the only marine fossils present. However, both of the formations have produced fossil plant fragments.

Miles 109 to 127

As we continue westward along I-68, we will pass through road cuts in Middle and Upper Devonian deposits. The ridge directly ahead is Town Hill, a sister ridge of Sideling Hill. Town Hill is also underlain by Mississippian Rockwell and Purslane strata. We will pass to the south of Town Hill, and continue westward through Devonian strata. At the crest of Polish Mountain note an excellent exposure of the Upper Devonian Brallier Formation. As we descend the west flank of Polish Mountain we will be going down stratigraphically until we reach the next stop.

STOP 4

Flintstone Bioherm in the Keyser Formation

Introduction

The purpose of this stop is to allow an opportunity to examine a small coralline/stromatoporoid bioherm in the Keyser Formation, noting both its depositional setting and faunal succession. The bioherm was partially destroyed during the construction of I-68, but sufficient portions remain to allow examination.

Bioherms and reefs have been previously

described from the Keyser Formation of Virginia and Pennsylvania by Smosna and Warshauer (1979) and Brezinski and Kertis (1982). Smosna and Warshauer (1979) described what appears to be a similar bioherm from regressive facies of the Lower Devonian part of the upper Keyser Formation from Highland County, Virginia. Conversely, the Late Silurian bryozoan mud mound described by Brezinski and Kertis (1982) appears to have formed in transgressive facies.

Stratigraphy

The bioherm is present within the upper strata of the Keyser Formation. As you walk from west to east, along either the highway or the first berm above, you should note that the main lithology within the Keyser Formation here is the nodular-bedded, fossiliferous limestone, similar to that characterizing the formation at Stop 2. Unlike Stop 2, at this stop the nodular wackestone strata give way upsection first into coarser wackestone and ultimately into pelmatozoan grainstone. Furthermore, the grainstone becomes coarser grained upsection and grades into a rudstone of the basal biohermal facies. This biohermal facies will be the main emphasis of this stop. When observing the outcrop from a distance, the bioherm stands out as an unbedded mass near the top of the exposure (Figure 10A).

Depositional Environments

Head (1969) and Dorobek and Read (1986, fig. 5A) produced facies tract maps of the lithologies manifested within the Keyser Formation in the central Appalachian Basin. Dorobek and Read (1986) interpreted the upsection change from nodular-bedded wackestone to grainstone, which characterizes the upper Keyser in this region, as indicating a regional regression. This regression is interpreted as resulting in the seaward progradation of shallow water grainstone facies of the bank environments over nodular wackestone of the deeper water shelf. With this in mind, the initiation and development of the biohermal facies within the grainstone lithology are directly related to the development of the bank environment and its associated high-energy conditions.

Bioherm Description

As you proceed upsection (to the east) you will notice that the nodular-bedded wackestone becomes coarser-grained and progressively changes into a medium-bedded, pelmatozoan-bryozoan wackestone and packstone. These packstone deposits become coarser upsection and locally are interbedded with rudstones composed of ramose bryozoans and pelmatozoans (Figure 10B). Approximately 15 feet (5 meters) of these deposits are present. The first indication of bioherm development is 5 to 7 feet (1.75 - 2.3 meters) of grainstone/rudstone containing favositid corals, ramose bryozoans, and abundant pelmatazoan remains (Figure 10B). Within this interval are several interbeds of pelmatozoan grainstone. Above the coral/bryozoan rudstone, the structure of the bioherm becomes more chaotic and all bedding is lost. Throughout the next 25 to 35 feet (8 - 12 meters) the rock is composed of unbedded stromatoporoid rudstone and locally stromatoporoid framestone with an interstitial filling of pelmatozoan grainstone (Figure 10C). At many sites stromatoporoids are toppled or overturned, but locally a well developed framestone can be noted (Figure 10D). Within this interval the stromatoporiods are large, bulbous forms that range in size from as little as 6 inches (0.15 to 0.75 meters) to as much as 2 feet in diameter (0.6 meters)

b
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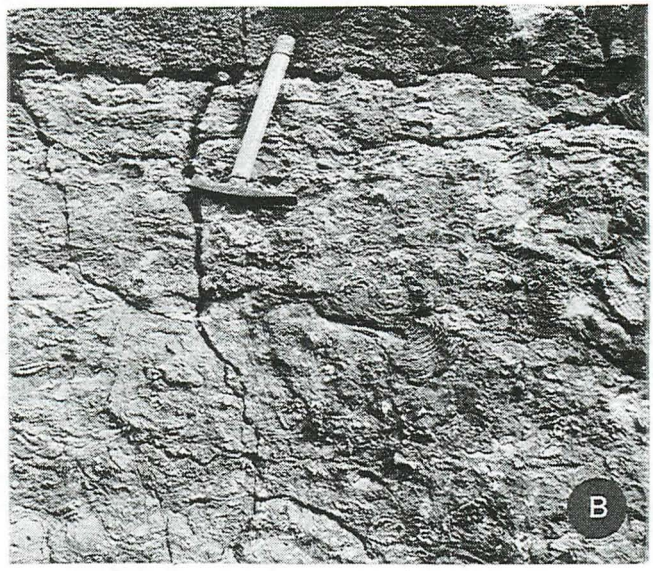
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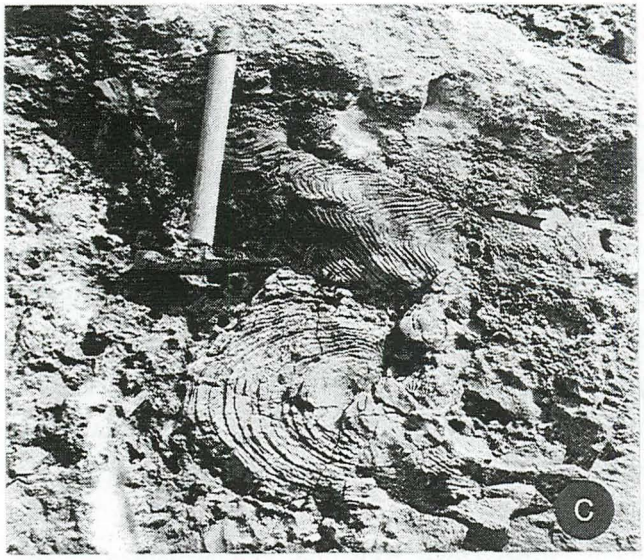
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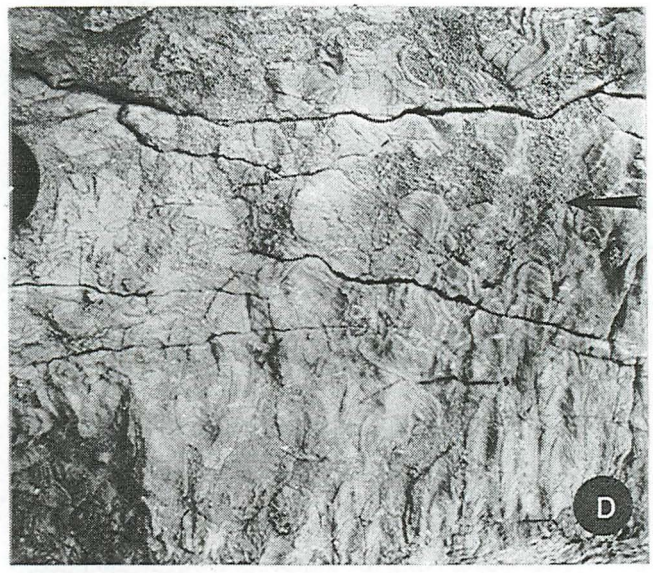
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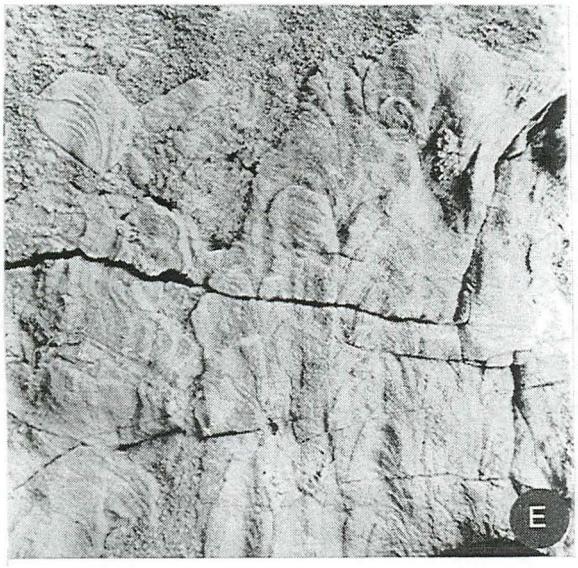
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F

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Figure 10.— A, Flintstone bioherm prior to I-68 construction, note unbedded appearance. B, bryozoan-stromatoporoid rudstone of the colonization stage. Note pelmatozoan grainstone (arrow) that sharply overlies rudstone. C, Stromatoporoid rudstone of the lower buildup. Note grainstone truncated reclined stromatoporoid at arrow. D, digitate to cylindrical stromatoporoid framestone overlain by fragmental stromatoporoid rudstone. E, Close-up of digitate stromatoporoids, buried by pelmatozoan grainstone. F, Top view of cylindrical stromatoporoid framestone at top of buildup.

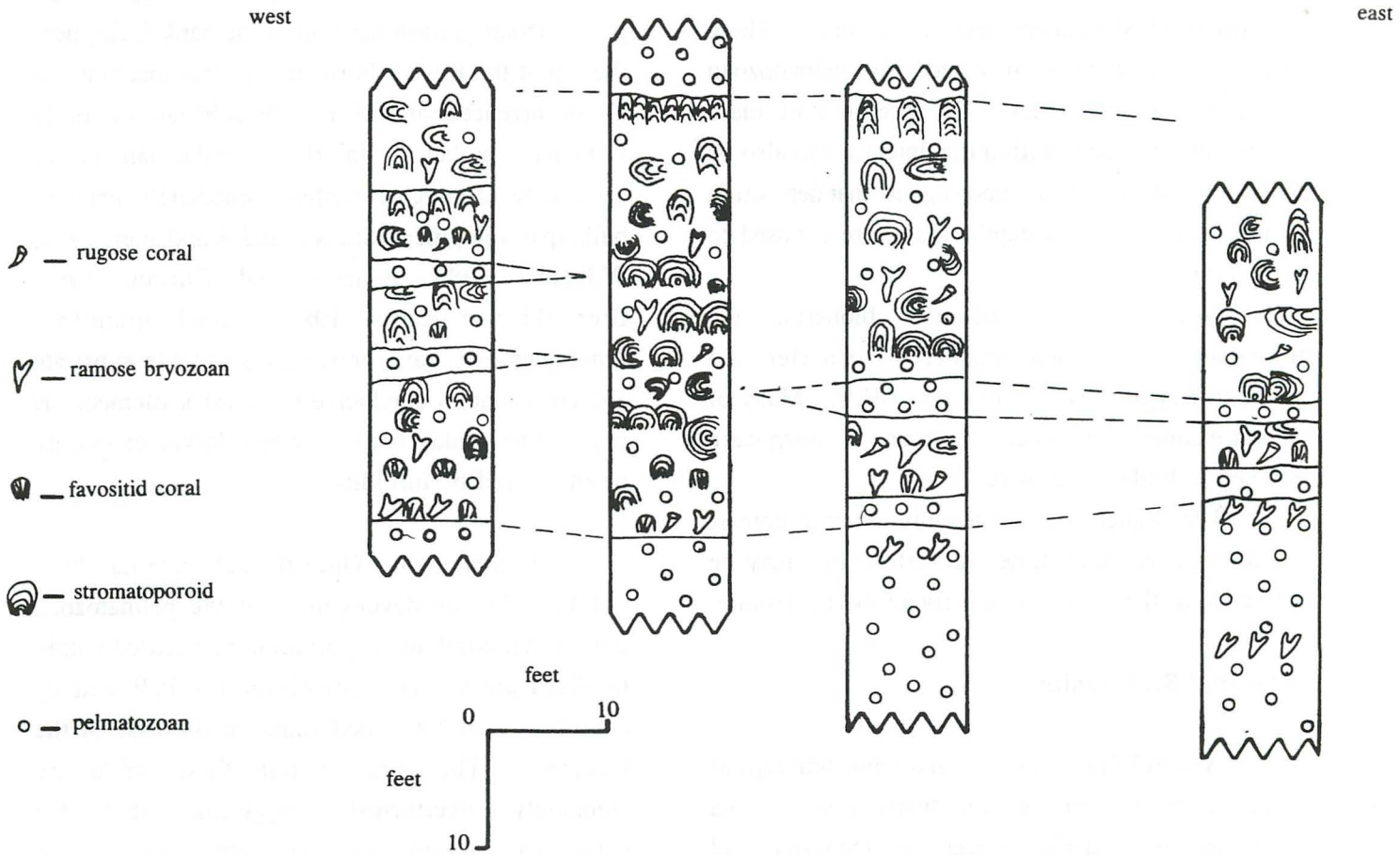

Figure 11.— Detailed stratigraphic sections of the Flintstone buildup prior to I-68 construction.

The overturned stromatoporoid colonies attest to the strength of the currents that must have existed during the deposition of this interval.

Several intervals within the bioherm contain bedded pelmatozoan grainstone, but these appear to be concentrated along what is interpreted as the flanks of the buildup. These grainstone intervals may represent storm deposits that periodically buried the stromatoporoids of the bioherm core. However, they may also represent short term shallowing episodes that exposed the buildup to erosion.

Prior to highway construction the highest biohermal beds contained numerous discontinuities that truncated stromatoporiod framestone. These discontinuities were then buried by pelmatozoan grainstones (Figure 10E). The presence of these discontinuity surfaces within this interval can also be attributed to storm erosion and suggest that deposition occurred within waters depths that were exposed to storm surges.

Near the top of the bioherm, the stromatoporoids become smaller in diameter and more cylindrical in shape (Figures 10E,F). Many of the best examples of this change in growth form were removed in highway construction.

The highest strata currently exposed consist of a dark gray, sandy lime wackestone that may be assignable to the overlying Corriganville Limestone.

Biohermal Succession

Within Silurian-Devonian organic buildups of the Appalachians, the vertical distribution of biota recurs in an orderly succession (Smosna and Warshauer, 1979; Isaacson and Curran, 1981; Brezinski and Kertis, 1982) (Figure 11). This recurring biotic arrangement has been termed faunal succession by Walker and Alberstedt (1975). Each of the three papers on Silurian-Devonian succession within small buildups suggests that three stages of succession are evident; whereas, within large buildups four stages are commonly recognized. The reasons for this discrepancy are not clear, but differences probably result from the ephemeral environmental settings of these buildups within relatively shallow, unstable regressive environments. For the Flintstone buildup the successional stages are discussed below.

Stabilization: As with most organic buildups, stabilization of the substrate is needed to allow settlement of viable larvae. This stage was accomplished with the development of the bedded pelmatozoan grainstones within the bank facies near the top of the Keyser Formation at this location. In all occurrences of either Late Silurian or Early Devonian bioherms in the Appalachian basin, grainstone lithologies existed immediately prior to buildup development (Smosna and Warshauer, 1979; Williams, 1980; Isaacson and Curran, 1981; Brezinski and Kertis, 1982). Such grainstone lithologies may have presented a suitable substrate and clear waters conducive to larval settlement, as opposed to muddy bottoms where larvae can easily be smothered by turbidity.

Colonization: Once the substrate had been stabilized by the development of the pelmatozoan grainstone, coral and bryozoan larvae settled within localized areas. This colonization is indicated by coral/bryozoan-dominated rudite at the base of the bioherm. The corals within these strata are commonly overturned, suggesting that the environment, although favorable for larval colonization, was still relatively unstable.

Diversification: This stage is not well exhibited within the Flintstone bioherm. The reason for this is not clear. Based on the thinness of the colonization deposits, soon after corals colonized the

area, stromatoporoids began to dominate the fauna.

Domination: The greatest thickness of the bioherm is composed of stromatoporoid rudite in which the large, bulbous stromatoporoids, up to 2 feet (0.75 m) in diameter, make up the greatest volume of the rock. A low-diversity fauna composed of pelmatozoans and bryozoans make up the inter-stromatoporoid infilling. Within this portion of the bioherm, bulbous stromatoporoids typically make up 65 to 75 percent of the rock. Even some of the largest stromatoporoid heads are overturned, attesting to the high-energy environmental conditions. Within the localized framestone intervals, stromatoporoids comprise as much as 90 percent of the rock. Clearly, stromatoporoids are the dominant faunal component within this interval.

The faunal succession of the Flintstone bioherm is similar to that observed by other authors (Isaacson and Curran, 1981; Brezinski and Kertis, 1982) in that small buildups, such as this one, do not have the four-fold successional stages as described for large reef masses by Walker and Alberstedt (1975). These small, short-lived buildups consistently contain wave-scoured surfaces. Their relatively short life span can be related to ephemeral conditions consistent with the rapidly changing environmental settings that characterize transgressive and regressive facies within epeiric seas. Consequently, the bioherm height is dictated by water depth and the duration of suitable environmental conditions.

Collecting

At this stop collecting is largely restricted to the bioherm and its associated beds. Although subjacent strata also are fossiliferous, they are not highly productive.

Miles 127 to 133

Along this stretch of I-68 the small exposures are primarily Silurian rocks. Several small exposures of red shales and sandstones of the Bloomsburg Formation and gray, shaly limestone of the Mckenzie Formation can be seen. Near the crest of Martin Mountain, thin, platy limestone of the Tonoloway Formation is folded into a number of anticline and syncline pairs. Exit I-68 at Rocky Gap State Park.

STOP 5

Silurian strata of the Rose Hill through Wills Creek Formations

Introduction

At this stop, along the north side of I-68, we will have an opportunity to examine Middle to Upper Silurian units of the Valley and Ridge Province in Maryland along approximately 1 mile (1.6 kilometers) of discontinuous outcrop (see Figure 1). This section exposes rocks of the upper Rose Hill Formation, Keefer Sandstone, McKenzie Formation including the Rochester Shale Member at the base, and Wills Creek and Tonoloway Formations at the top. The Bloomsburg Formation is not exposed. We will begin at the base of the Tonoloway Formation and work our way down stratigraphic section through the Wills Creek to the McKenzie, Keefer, and Rose Hill Formations.

Stratigraphy

The section begins along the entrance ramp of westbound I-68 within the basal strata of the Tonoloway Limestone. Only a few feet of this unit is exposed; however, one can get an idea of the

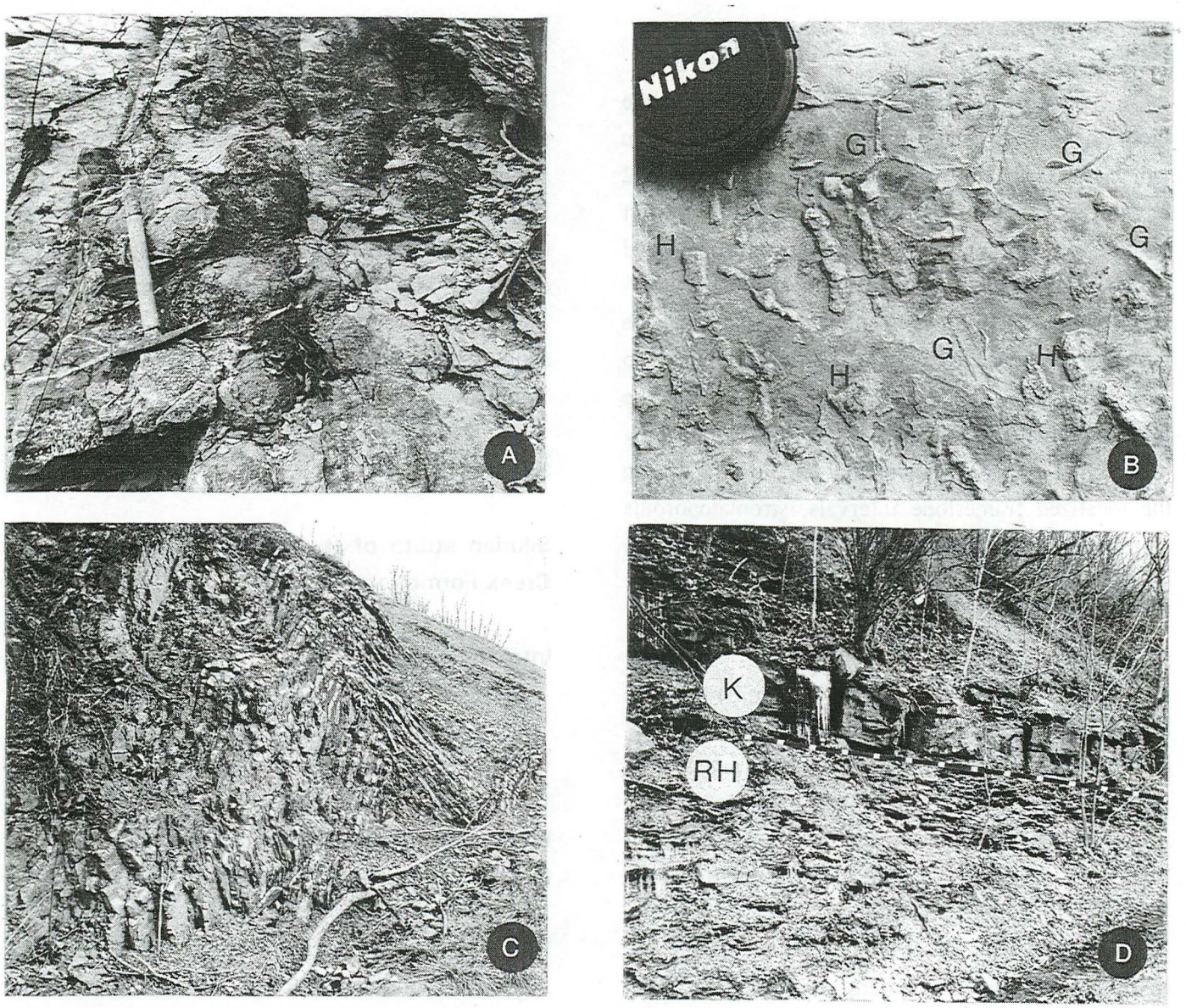

Figure 12.— A, Top view of domal stromatolites within the upper Wills Creek Formation. Note subjacent mudcracked surface in upper left of photograph. B, Halite (H) and gypsum (g) casts from the upper Wills Creek Formation. D, Folded thinly interbbed limestone and shale that characterizes the McKenzie Formation of western Maryland. E, Exposure of the Keefer Sandstone (K) and underlying Rose Hill Formation at the base of exposure at Stop 5.

lithologic composition of the formation from this interval. The Tonoloway consists of very thinly bedded, to thinly laminated, shaly limestone. The formation characteristically weathers into tan, platy and shaly chips. As we continue westward (downsection), we will pass into the Wills Creek Formation. The Wills Creek is characterized by medium-bedded, gray-green to tan weathering,

calcareous shale and laminated, silty dolomite. The formation contains pervasive horizons of desiccation cracks and domal stromatolites (Figure 12A). Salt and gypsum casts are also common in some intervals near the top of the formation (Figure 12B). The Wills Creek Formation is approximately 500 feet (155 meters) thick in this area (Swartz, 1923). It is correlative to the salt beds of the Salina Formation that occur in the subsurface to the west in Pennsylvania and West Virginia, and to the north in New York.

Progressing downsection, we will pass through a concealed section (valley). It is within this interval that the Bloomsburg Formation occurs. In this area the Bloomsburg is less than 50 feet (15 meters) thick (DeWitt and Colton, 1964). Continuing downsection to the next exposure we will see the underlying McKenzie Formation. The McKenzie in this area is composed of interbedded medium gray shale and thin-bedded, dark gray limestone (Figure 12C). The shales are essentially devoid of fossils; whereas, the limestones commonly are coquinas of brachiopod and ostracode valves and locally snails. Each limestone stratum typically exhibits graded bedding when viewed in cross section. At some locations, hummocky cross-stratification is also evident within the limestone beds. These thin limestone intervals probably were deposited by waning storm currents. At the base of the formation an interval of shale, termed the Rochester Shale Member, is present, but not well exposed. The thickness of the McKenzie Formation is approximately 250 feet (80 meters) in this area (Swartz, 1923).

The lowest strata that we will examine at this exposure will be within the Keefer Sandstone and Rose Hill Formation. These two units are exposed near the overpass bridge abutments. The Keefer consists of approximately 18 feet (6 meters) of thin- to medium-bedded, argillaceous, locally fossiliferous, ferruginous sandstone (Figure 12D). The uppermost 3 feet (1 meter) consists of ironstone. Underlying the Keefer Sandstone is the Rose Hill Formation. Unfortunately, we will have an opportunity to examine only the uppermost portion of the formation. Approximately 30 feet (10 meters) of greenish-gray shale occurrs near the base of the bridge. This 30 feet makes up only a small portion of the more than 500 feet (155 meters) of stratigraphic section that comprise the Rose Hill Formation. Possibly the most interesting lithology within this formation is an ironstone unit, locally known as the Cresaptown Ironstone, that occurs approximately 200 feet (60 meters) above the base of the formation. This interval is exposed a mile to the west, along the north side of the interstate. You should to keep an eye out for it as we drive westward after we leave this stop. The Rose Hill Formation is correlative to the Clinton Formation of New York State.

Depositional Environments

Table 2 gives a summary of the stratigraphy and depositional environments for the Silurian sequence exposed at Stop 5. The Rose Hill Formation represents a sequence of shallow marine shale that extended, during deposition, from New York to Tennessee (Smosna and Patchen, 1978). Regional regression during the Middle Silurian permitted the development of shallow shoal and beach deposits of the Keefer Sandstone to form. Deepening, following deposition of the Keefer, created a shallow, muddy shelf environment on which the Rochester Shale and the McKenzie Formation were deposited. The shoreline again prograded seaward with the deposition of the Bloomsburg Formation clastic wedge. Following the deposition of the Bloomsburg Formation, a large restricted salt basin developed to the west in West

formation	*lithology*	*environment*	*sea level* deeper →
Tonoloway	laminated limestone	tidal flat	
Wills Creek	cyclic shale and dolomite	sabkha	
Bloomsburg	red shale and sandstone	prograding clastic wedge	
McKenzie	interbedded limestone and shale	shallow nearshore subtidal shelf	
Rochester Mbr.	gray shale	shallow shelf	
Keefer	red sandstone	restricted beach	
Rose Hill	red and green-gray shale	nearshore muddy shelf	

Table 2.— Summary of relationship between stratigraphic nomenclature, lithology, depositional environment, and sea level curve for Silurian units of western Maryland.

Virginia and western Pennsylvania (Smosna and Patchen, 1978). Along the eastern margin of this salt basin, supratidal mud flats and sabkhas of the Wills Creek Formation were deposited. The shaly mud flat deposition continued through most of the Upper Silurian with the deposition of the Tonoloway Formation. During the latest Silurian, the central Appalachian Basin was once again submerged with normal marine waters as the Keyser Formation was deposited.

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