I-68/I-70: A WINDOW TO THE APPALACHIANS

by

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Introduction

The Appalachian Mountains are probably the most studied mountains on Earth. Many of our modern ideas as to the origin of major mountain systems evolved from early investigations of the Appalachian region. The Appalachians offer a unique opportunity to experience the various components of an entire mountain system within a relatively short distance and period of time. Compared to the extensive areas occupied by other mountain systems such as the Rockies and the Alps, the Appalachians are relatively narrow and can be easily crossed within a few hours driving time. Following I-68 and I-70 between Morgantown, WV, and Frederick, Maryland, for example, one can visit all of the major structural components within the Appalachians within a distance of about 160 miles.

Before I continue, I would like to clarify references to the Allegheny and Appalachian mountains. The Allegheny Mountains were created about 250 million years ago when continents collided during the Alleghenian Orogeny to form the super-continent of Pangea (Figure 1). As the continents collided, a range of mountains were created in much the same fashion that the Himalaya Mountains are now being formed by the collision of India and Asia. About 50 million years after its

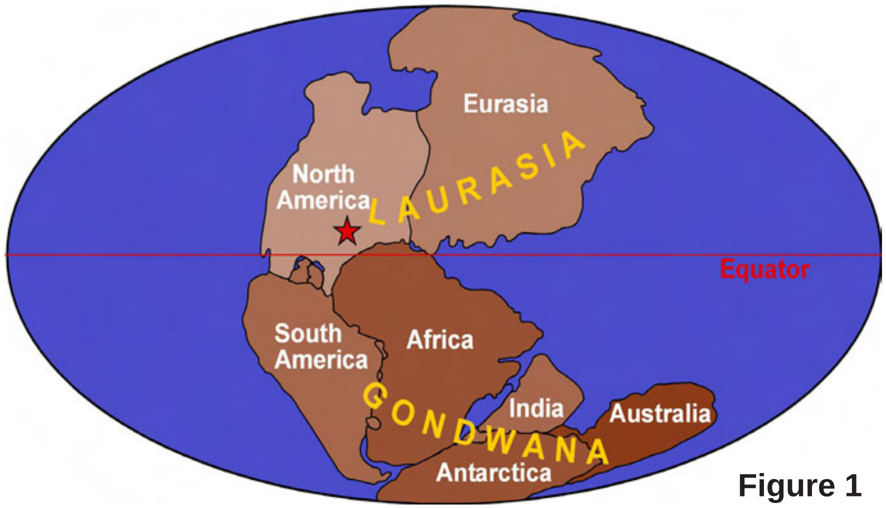


Figure 1

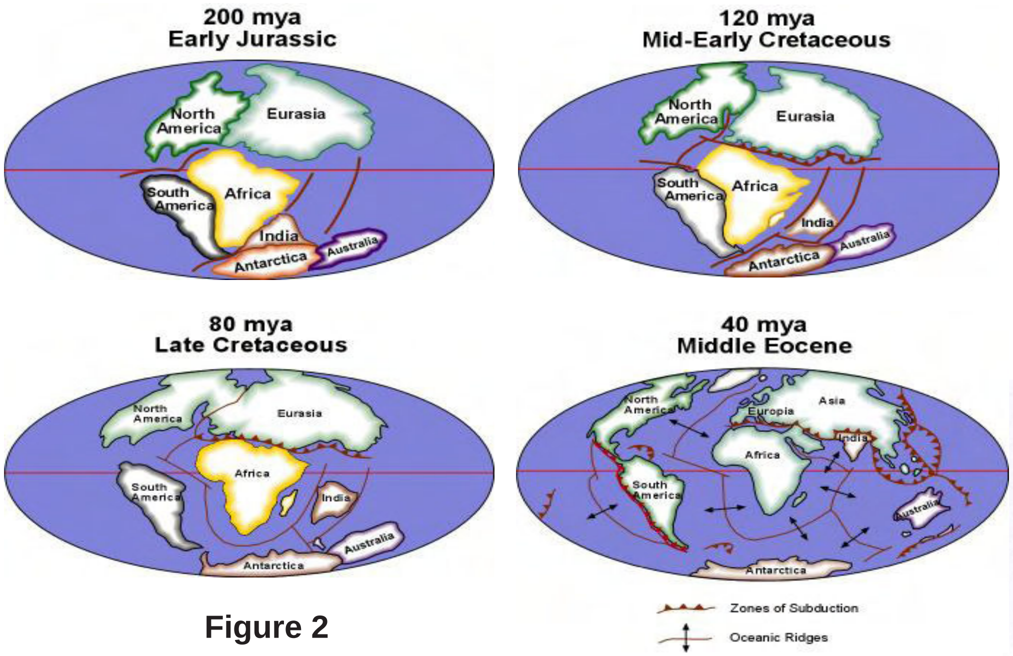


Figure 2

creation, Pangea began to break up with the break occurring parallel to the axis of the original mountains. As the pieces that were to become our present continents moved away from each other, the Indian, Atlantic, and Arctic oceans were created (Figure 2). As North America split away from Europe and North Africa, part of the mountain chain went with North America to eventually become our present Appalachians while the rest of the mountain chain remained with Africa and is now to be found in North Africa as the Atlas Mountains

with some of the rocks exposed in Europe from northern Ireland through Scotland to Scandinavia. Over the next 100 million or so years, the combined efforts of weathering, mass wasting, and erosion wore the topography of the original Allegheny Mountains down to a flat, featureless plain nearly at sealevel. About 60 million years ago, the entire eastern portion of North America from the continental interior to the east coast was uplifted into a broad arch with the apex rising about 5,000 feet (1,525 m) above sea level. As the existing streams, rejuvenated by the uplift, began to carve their channels down to the newly formed baselevel, the present topography of the Appalachian region emerged. A schematic representation of the evolutionary history of the Appalachians is illustrated in Figure 3. It is important to keep in mind as you traverse the Appalachians along the route of I-68 and I-70 that the *structures* you see, the folds and faults, are very old, dating back to the Alleghenian Orogeny 250 million years ago, while the present *topography* of the region we now know as the Appalachian Mountains is the result of erosion that has taken place over the past 60 million years.

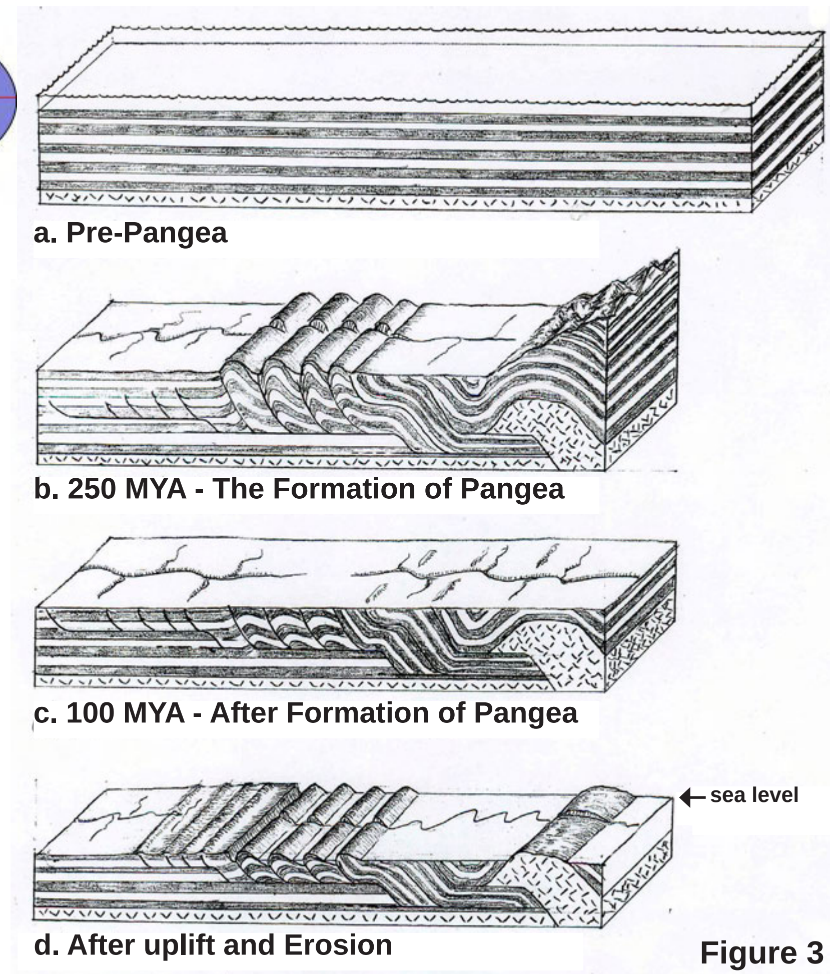


Figure 3

Basic Geologic Information and Principles

In order to help you better understand what you will see along the route of the trip, I have included a review of some basic geologic topics.

Geologic Structures: The geologic structures are *folds*, *faults*, and *joints*. The dominant structures you will see during this field trip are folds. Based on their shape, folds are divided into *symmetric*, *asymmetric*, *overturned*, and *recumbent* (Figure 4).

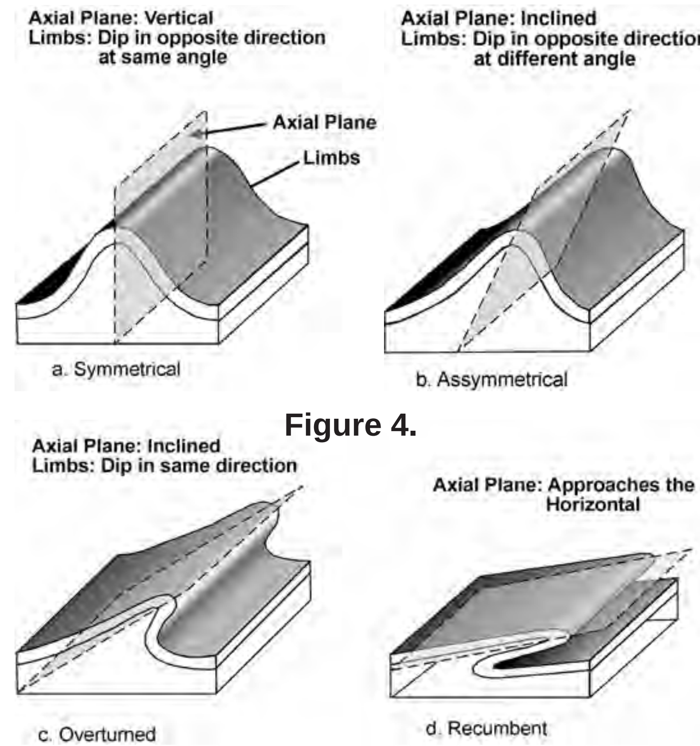


Figure 4.

Three criteria are used to describe the shape of folds: 1) the attitude of the *limbs*, 2) the attitude of the *axial plane*, and 3) the angle, called the *dip*, that the limbs make with the horizontal. The axial plane is an imaginary plane drawn parallel to the long dimension of the fold that attempts to divide the cross section into equal halves. A symmetric fold has a vertical axial plane with limbs that dip away from each other at equal angles of dip (refer to Figure 2). The axial plane of an asymmetric fold is inclined with the limbs dipping away from each other, but at different angles of dip. Overturned folds are those whose limbs dip in the same direction. A recumbent fold is defined as one whose axial plane and limbs approach the horizontal. Except for the recumbent style, you will see examples of all of the fold types as the trip progresses.

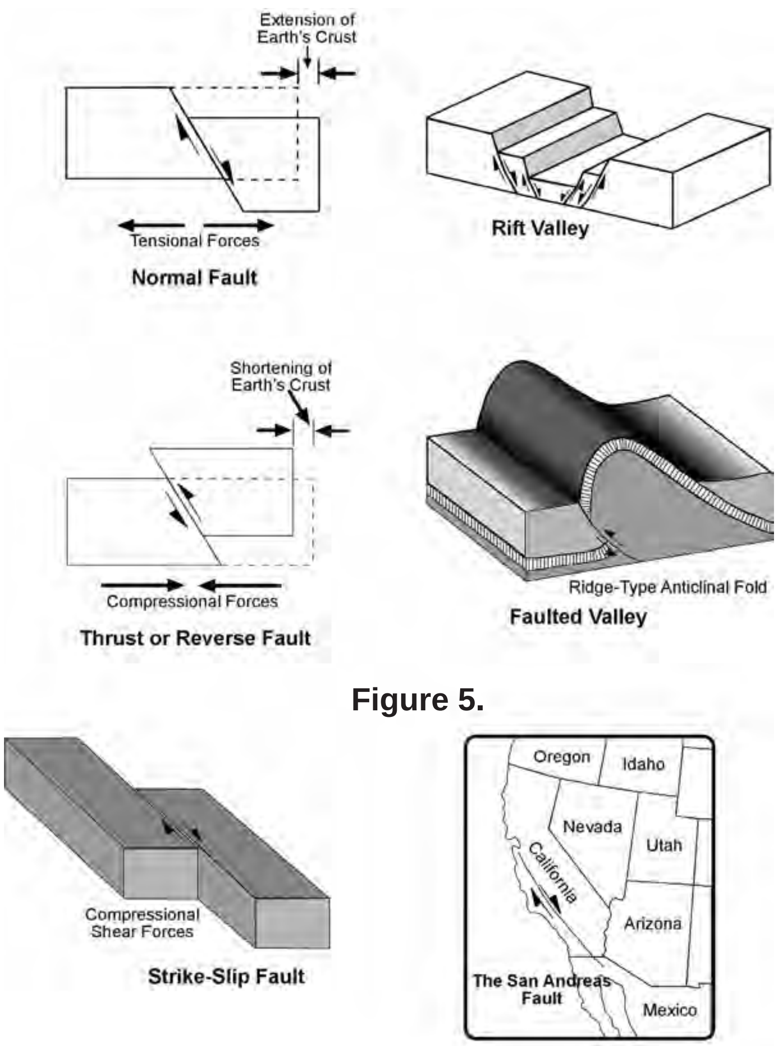


Figure 5.

The three major types of faults, *thrust* (or *reverse*), *normal*, and *strike-slip* are illustrated in Figure 5. Although faults are present throughout the Appalachians where their presence plays a major role in much of topography and structures you will see, their presence is not as evident at the surface as are the folds. Of the three types of faults, thrust faults dominate throughout the Appalachians, reflecting the compressional forces responsible for the formation of the mountains.

Joints are fractures in rocks along which there has been no appreciable movement. All rocks everywhere contain joints as will be evident in every rock outcrop exposed along the roadway.

Stratigraphy: Stratigraphy is the study of sedimentary rocks. A characteristic of all sedimentary rocks is that they are **bedded**. Initially, all sediments are laid down horizontally with the oldest layer being on the bottom with the overlying layers becoming progressively younger. Whether they now appear horizontal at the surface depends upon the kind of deformation they have been subjected to subsequent to their being converted into rock. If they are simply uplifted, the bedding of the rocks exposed at Earth's surface will still be horizontal. An excellent example are the rocks seen in the Grand Canyon that are the result of the vertical uplift of the Colorado Plateau over the past 20 million years. If, on the other hand, the rocks were subjected to compressive forces, as in the case of the Appalachians, the rocks will undergo folding.

Whether flat-lying or folded, the sedimentary rocks found in any area are summarized in a **stratigraphic column** which shows the vertical sequence of the rocks and their relative ages. The stratigraphic column for this trip is found in Figure 6. One of the most difficult aspects of any geology field trip is to keep track of the various rock units you will be seeing. I would suggest that you keep Figure 6 conveniently available so that you can readily refer to it to identify the stratigraphic location of the rocks you will see.

Bedding Attitude: Throughout most of this trip, the sedimentary rocks were uplifted with compressional deformation that resulted in the beds being folded and faulted. In the area of Morgantown and to the west, in a region called the Appalachian Low Plateau. The structures underlying the Low Plateau are symmetrical folds with amplitudes so small that the rocks appear horizontal. A few miles east of Morgantown, you will leave the Low Plateau and enter The Appalachian High Plateau. While the structures underlying the High Plateau are mostly symmetrical folds, the amplitudes of the folds are high enough that the structures form ridges. As you drive eastward across the High Plateau, the fold amplitudes and the angle of the bedding observed in the outcrops along the roadway changes. In one exposure, the bedding may be horizontal while in others, it may dip toward you (to the west) or away from you (to the east) Get into the habit of paying attention to the attitude of the bedding of the rocks along the roadway. In areas of folded rocks, the bedding will be horizontal as you cross the axis of an anticline or a syncline. As you approach the

Figure 6: Stratigraphic Column

Pennsylvanian System
- Dunkard Group
- Monongahela Formation
- Conemaugh Formation
- Allegheny Formation
- Pottsville Formation

Mississippian System
- Mauch Chunk Formation
- Greenbrier Formation
- Pocono Group
  - Purslane sandstone
  - Rockwell Formation

Devonian System
- Hampshire Formation
- Chemung Formation
- Foreknobs Formation
- Brallier Formation
- Hamilton Group
  - Mahatango Formation
  - Harrell/Marcellus shale
  - Needmore shale
- Oriskany sandstone
- Helderberg Formation
- Keyser formation

Silurian System
- Tonoloway limestone
- Wills Creek Formation
- Bloomsburg Formation
- McKenzie Formation
- Clinton Group
  - Rochester shale
  - Keefer sandstone
  - Rose Hill Formation
- Tuscarora sandstone

Ordovician System
- Juniata Formation
- Martinsburg Formation
- Chambersburg Formation
  - Chambersburg limestone
  - New Market limestone
  - Row Park limestone
- Beekmantown Group
  - Pinesburg Station dolomite
  - Rockdale Run Formation
  - Stonehenge limestone

Cambrian System
- Conococheague limestone
- Elbrook limestone
- Waynesboro Formation
- Weverton Formation

pre-Cambrian System
- Catoctin Formation

axis of an anticline, the bedding will dip *toward* you (Figure 7). Because all of the folds in the Appalachians trend NE-SW, this will be to the west. Note also that as you approach the axis of an anticline, the rocks become progressively *older*, that is you are going *down* stratigraphically. In any area of folded rocks, the oldest rocks will be exposed in the axis of a breached anticline or in the center of a water gap cutting through an anticlinal fold. Conversely, as you drive toward the axis of a syncline, the bedding will dip *away* from you (in this case to the east) and the rocks will become progressively younger; you will be going *up* stratigraphically. In an area of folded rocks, the youngest rocks will be found in the axial region of a syncline which, most often, will be a valley floor. Monitoring the attitude of the bedding as you drive is the best way for you to keep track of the folds that you will be crossing.

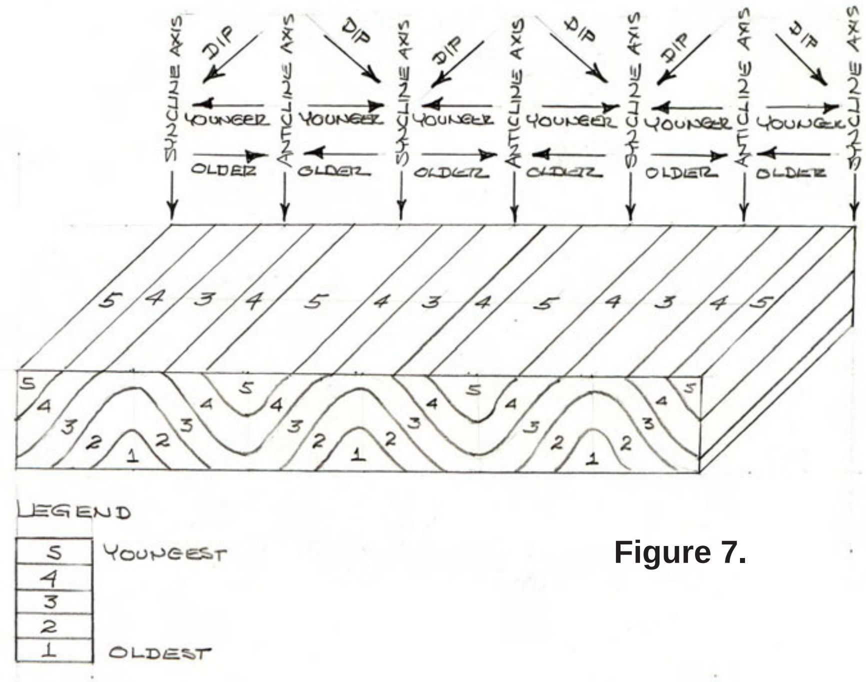


Figure 7.

Physiographic Provinces

Continents are subdivided into *physiographic provinces*. A physiographic province is defined as a region of which all parts are similar in geologic structure and climate and which has had a unified geomorphic history; a region whose pattern of landforms differ significantly from that of adjacent regions. The Appalachian region is divided into four physiographic provinces, which are from west to east: the *Appalachian Plateaus*, the *Valley and Ridge*, the *Blue Ridge*, and the *Piedmont* (Figure 8). While the trip will terminate in the Piedmont, many geologists do not consider the Piedmont Province as being part of the Appalachians.

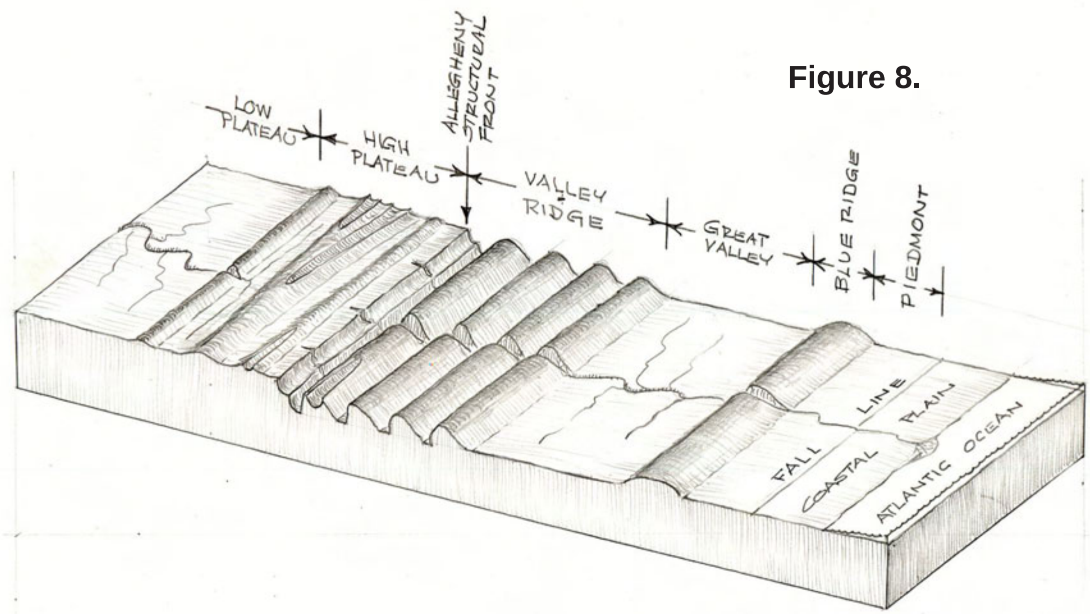


Figure 8.

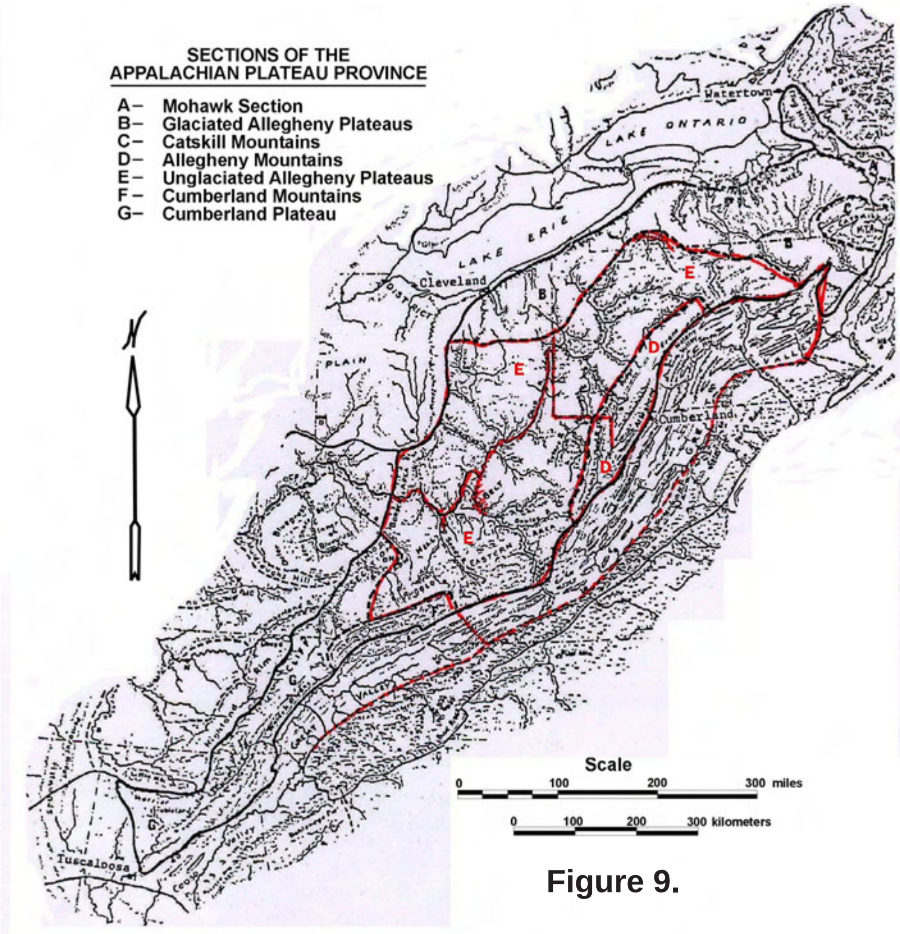


Figure 9.

As the name implies, there are several Appalachian plateaus (Figure 9). The most northerly plateau, the Mohawk Plateau, extends northward from the Mohawk and Hudson rivers into New England. Next, the Glaciated Allegheny Plateau extends from the Mohawk Plateau southward to the maximum extent of the Pleistocene ice advance just south of the New York-Pennsylvanian border. The largest plateau, the Unglaciated Plateau, extending southward to Kentucky, is divided into an eastern Allegheny Mountain Section or High Plateau, a western Low Plateau, and the southernmost Cumberlsand Plateau. The terms, High and Low Plateau are my own means to designate the two basic regions within the Unglaciated Plateau.

The Valley and Ridge Province is subdivided into the eastern Great Valley Section and the western Appalachian Mountain Section.

Appalachian Low Plateau: The Appalachian Low Plateau is the westernmost of the Appalachian Plateaus Physiographic provinces. The Low Plateau is largely underlain by rocks of Pennsylvanian age (refer to stratigraphic column in Figure 6). Morgantown is located near the eastern edge of the Low Plateau. As previously mentioned, the rocks exposed in road cuts from Morgantown are deformed into very low amplitude symmetrical folds that appear as though they are perfectly horizontal. The reason why the bedding appears to be horizontal is because the dips on the limbs are so low (generally less than 2^{o} or 3^{o}) that the human eye cannot discern any dip on the beds. Although faults are probably present in the area, they are of very low displacement and are rarely seen at the surface.

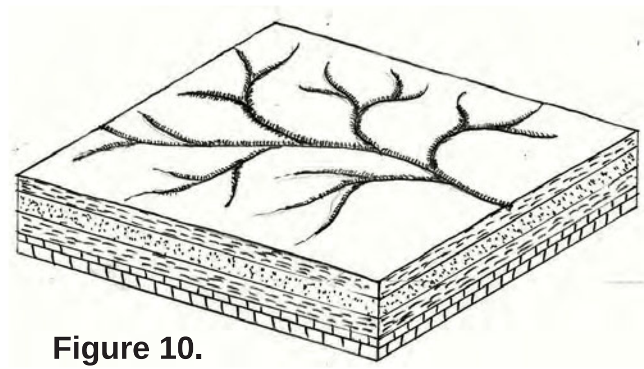


Figure 10.

Typical of areas underlain by essentially horizontal rocks, the dominant stream pattern throughout the Low Plateau is dendritic (Figure 10). In general, the streams have progressed to the mature stage of geomorphic development with most of the major streams having developed floodplains and meanders. Other characteristics of a mature topography include average distances from hilltops to valley floors, the *relief*, of a few hundred feet, with adjacent streams separated by rounded hills with relatively shallow slopes. The topography in the vicinity of Morgantown is typical of the province.

Most geologists consider the western limit for the Low Plateau to be located in central Ohio where glacial deposits and older Paleozoic rocks crop out. The easternmost limit of the Low Plateau and the beginning of the High Plateau is located just east of Morgantown at the western base of Chestnut Ridge. Chestnut Ridge is a dominant topographic feature that extends from just north of Uniontown, Pennsylvania, southwestward to Weston, West Virginia. The structure responsibly for the ridge, Chestnut Ridge Anticline, is a symmetrical anticline. The NE-SW trend of Chestnut Ridge, and of all of the other major Appalachian structures, is the result of the great pressures that were applied from the southeast when the Allegheny Mountains were created about 250 million years ago. One can compare and contrast the topography of the high and low plateaus by referring to the Morgantown 7.5' topographic map available from the West Virginia Geologic and Economic Survey.

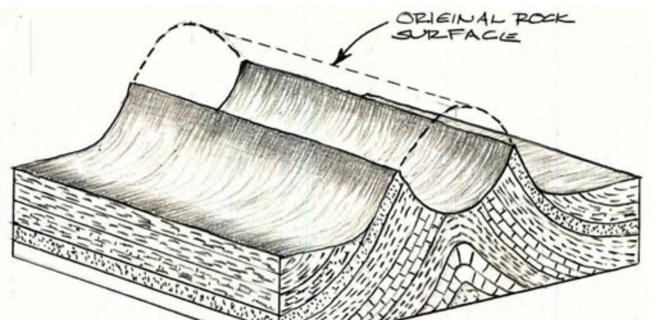
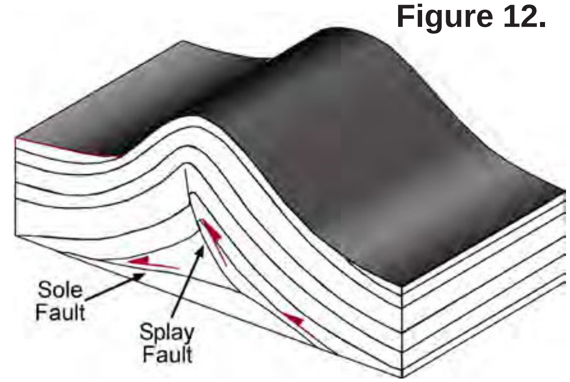


Figure 11.

The Alleghenian Mountain Section or Appalachian High Plateau: The Allegheny Mountain Section of the Unglaciated Plateau, or Appalachian High Plateau, extends from Chestnut Ridge on the west to the Allegheny Structural Front on the east (refer to Figure 8). Rocks within the province range in age from Pennsylvanian to Devonian with the oldest rocks being exposed in the axial regions of breached anticlines (Figure 11). The dominant structures within the High Plateau are relatively high amplitude symmetrical folds with the increased amplitudes of the folds being due to the presence of thrust faults within the anticlinal cores that provided a vertical displacement of the rocks within the fold (Figure 12). The effect of the increased fold amplitudes is an increase in regional relief that results in a more rugged terrain than that seen throughout the Low Plateau to the west. Because of the increased relief of the High Plateau over that of the Low Plateau to the west, the Appalachian High Plateau has also been referred to as the Allegheny Mountains or the *open-fold* section of the Appalachian Plateaus. From central Pennsylvania to central West Virginia, the eastern-most edge of the Appalachian High Plateau is called the Allegheny Strucutral Front (Figure 13).

Figure 12.


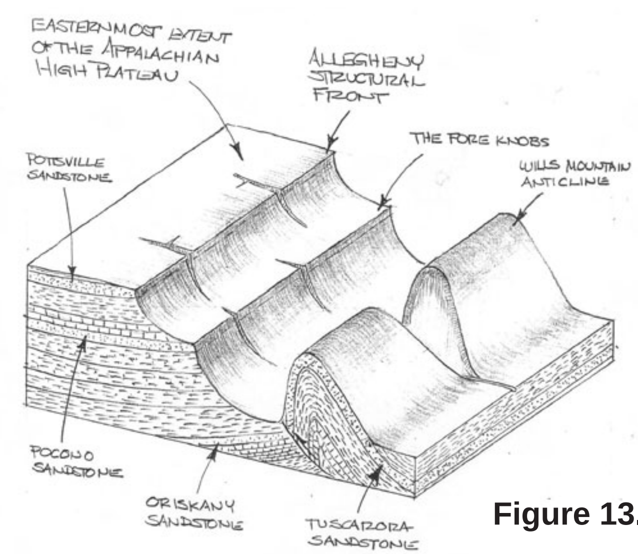


Figure 13.

It is important to note that the highest elevations in the Appalachians are found just west of the Allegheny Structural Front and not, as one might expect, in

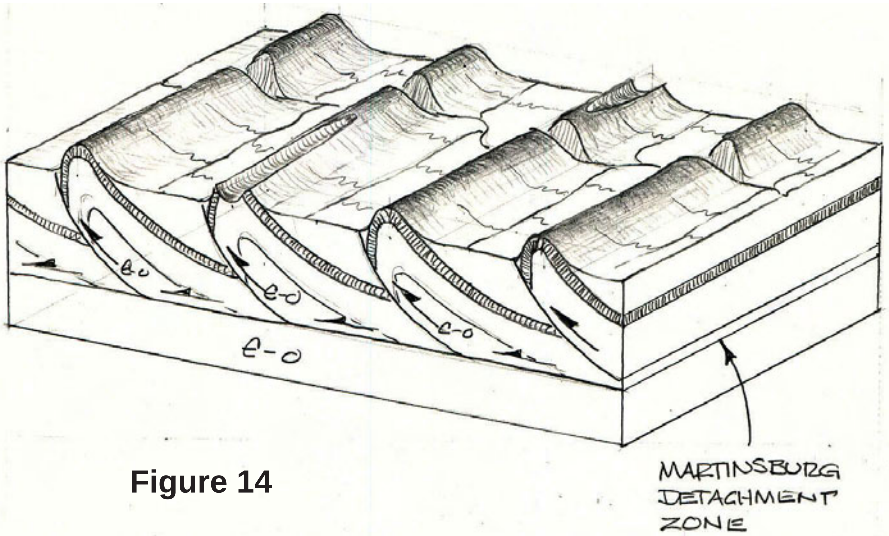


Figure 14

the Appalachian Mountains to the east. The reason for this rather anomalous situation is due to the fact that the apex of the broad arch that was uplifted about 60 million years ago from the Mississippi River Valley to the Atlantic Ocean is located along the eastern edge of the Appalachian Plateaus.

An important economic aspect of the Appalachian Plateau are the mineable coal deposits that are located within its boundaries with the coal beds being contained within the Pennsylvanian rocks. One particular coal bed, the Pittsburgh coal, often referred to as the most valuable rock layer in the world, accounts for 25% of all the coal mined in West Virginia.

Appalachian Mountain Section: The Appalachian Mountain Section of the Valley and Ridge Physiographic Province extends from the Allegheny Structural Front to the Great Valley and constitutes what is commonly referred to as the Appalachian Mountains. The name reflects the dominance of northeast-southwest-trending parallel valleys and ridges within the province. For the most part, the ridges are high amplitude asymmetric to overturned folds, commonly broken on the western limb by high-angle thrust faults (Figure 14). The oversteepening of the folds to the west indicates an east to west direction of rock transport during the original mountain building episode. The wavelength of the folds in the Valley and Ridge (the distance between fold axes) is significantly less than the wavelength of the more open folds in the High Plateau to the west. Many of the anticlinal structures have been breached by erosion, exposing the oldest rocks of the region, the Ordovician, within anticlinal valleys. An excellent example of a valley that formed as the result of the breaching of an anticline that you may be familiar with is Germany Valley located in Pendleton County, West Virginia (Figure 15).

There are occasional synclinal ridges that you will observe along your route, the most well known being

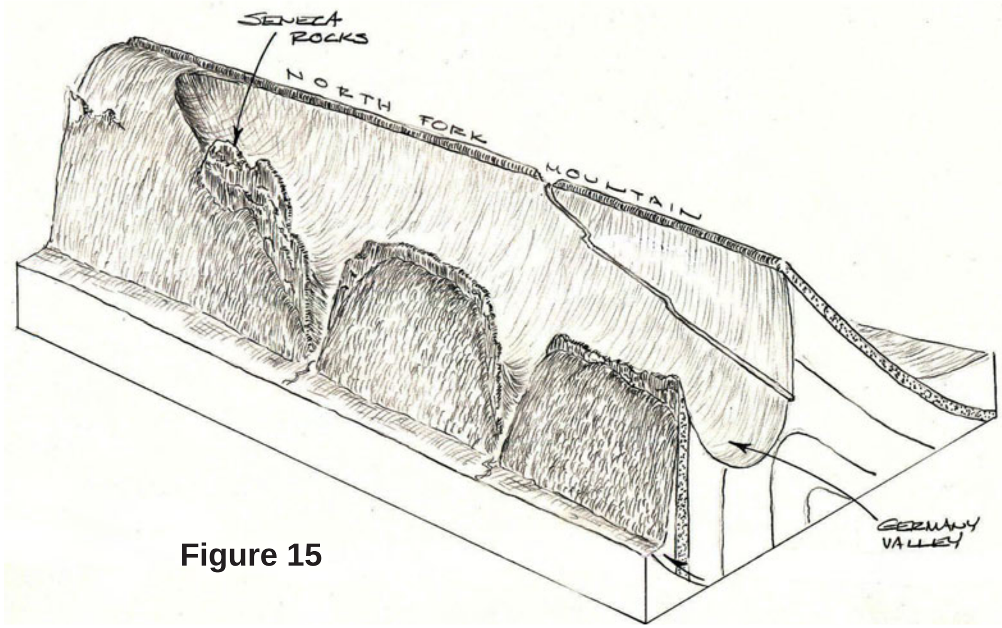


Figure 15

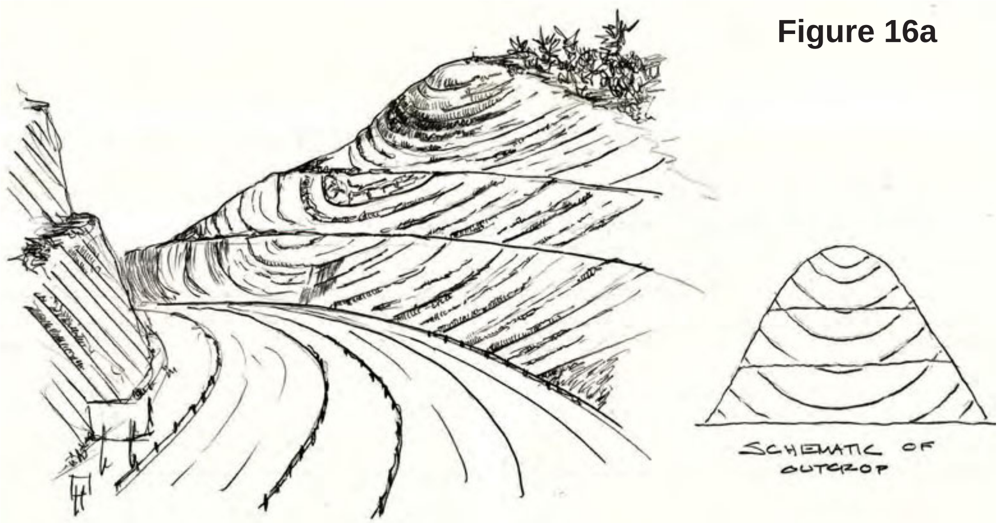


Figure 16a

Sideling Hill, Maryland. Synclinal ridges are formed as adjacent anticlines are breached with the subsequently valleys eventually being eroded below the elevation of the adjacent synclinal valleys, creating what geologists call “inverted topography”(Figure 16a and 16b). Eventually, the resistant rock layer becomes a tough caprock that remains high above the surrounding terrain as the rocks within the adjacent anticlinal structures are removed.

It is important to emphasize that the summits of all of the ridges within the Appalachian Mountains are lower in elevation that of the easternmost edge of the Appalachian Plateau with the elevations of each more easterly ridge being generally lower than that to the west. This relationship results in the rather unique situation of one going down into the Appalachian Mountains when approached from the west.

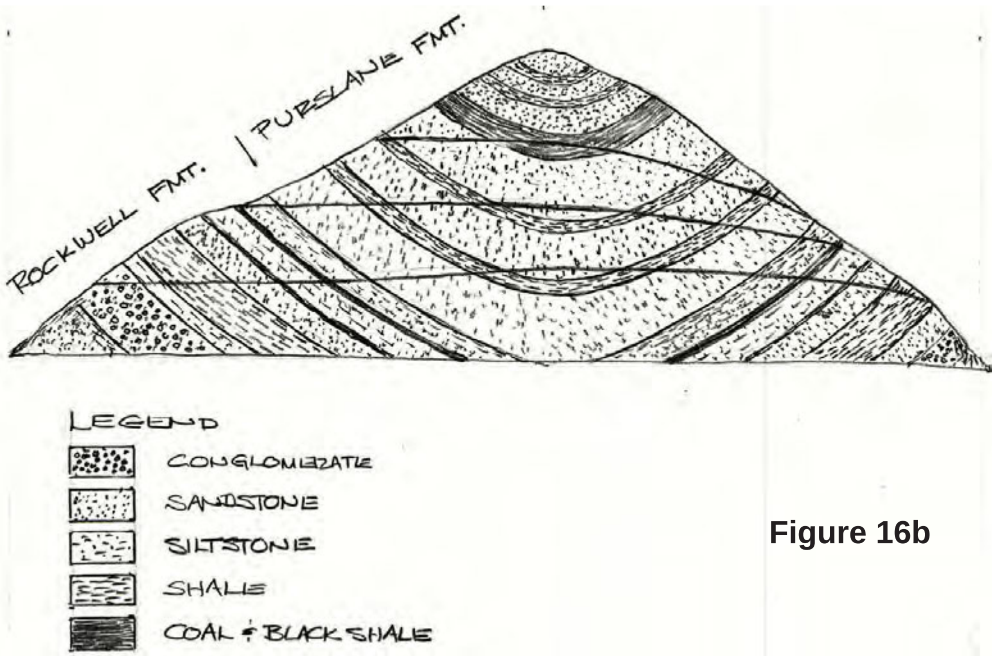


Figure 16b

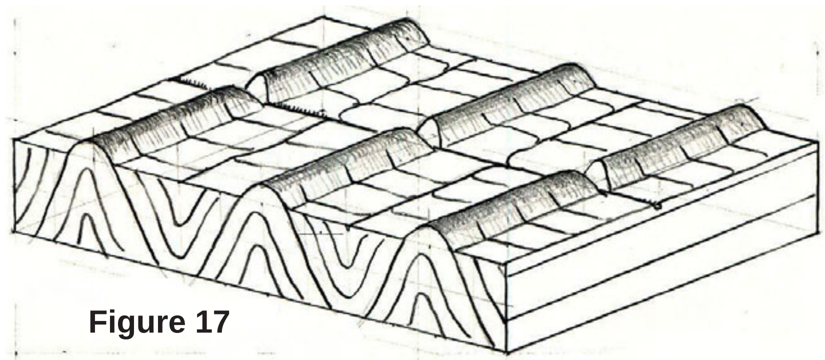


Figure 17

Because of the dominant northeast-southwest trending ridges and valleys, the stream pattern within the Valley and Ridge is *trellis* with the major streams cutting across the structures and tributaries draining the valleys (Figure 17). There is evidence that many, if not most, of the water gaps that cut across anticlinal structures follow vertical fault zones with the streams taking advantage of the zone of weakness.

The Great Valley Section: The Great Valley Section of the Valley and Ridge Province, commonly referred to as the Shenandoah Valley, extends eastward from the easternmost ridge of the Appalachian Mountain Section of the Valley and Ridge to the base of the Blue Ridge Mountains. Rocks within the valley are nearly all Cambrian and Ordovician limestones. Because of the water soluble nature of calcium carbonate, the rocks have been dissolved down to the mean level of the streams, resulting in a broad, flat valley. The few low ridges observed within the valley are in large part due to the occasional non-carbonate rock layer that is a bit more resistant to erosion. Although natural exposures of limestones are limited because of their solubility, numerous limestone rock outcrops can be seen in the fields. Typical of regions underlain by limestones, the soils are thin and are composed almost entirely of the insoluble materials, clay minerals and quartz, that were originally contained within the limestones. Also typical of areas underlain by limestones, the Great Valley shows extensive development of *karst topography* readily identified by the extensive number of sinkholes throughout the region (Figure 18). Because of their alkaline character, the soils are ideal for the growth of calcium-loving grasses which explains the widespread use of the land for the grazing of cattle. The red to orange color of the soil is typical of areas underlain by limestone and is due to the fact that the insoluble materials released by the dissolution of the limestones are coated by combinations of red iron oxides, Fe_2O_3, and yellow iron oxy-hydroxides, FeO(OH).

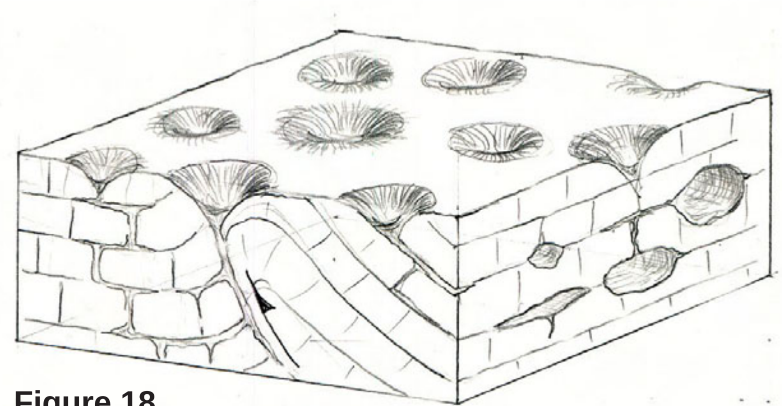


Figure 18

Structurally, the valley is underlain by many northeast-southwest trending high-displacement thrust faults and highly deformed asymmetric and overturned folds which, because of the limited exposures, are not always easy to observe. As one approaches the easternmost portion of the valley, the rocks show evidence of low-level metamorphism, the result of being located closer to the original zone of deformation (Table 1).

Table 1

ORIENTATION	WEST					EAST
FORCES	PASSIVE COMPRESSION ⇒					⇐ ACTIVE COMPRESSION
ENERGY AVAILABILILTY	MINIMAL					MAXIMUM
GEOGRAPHIC REGION	APPALACHIAN PLATEAU		VALLEY & RIDGE PROVINCE		BLUE RIDGE MOUNTAINS	PIEDMONT
	LOW PLATEAU	HIGH PLATEAU	APPALACHIAN MOUNTAINS	GREAT VALLEY		
FOLD GEOMETRY	LOW AMPLITUDE SYMMETRICAL	MEDIUM AMPLITUDE SYMMETRICAL	HIGH AMPLITUDE ASSYMETRICAL	HIGH AMPLITUDE ASSYMETRICAL	RECUMBENT	HIGHLY DEFORMED PLASTIC FLOW
FAULTS (REVERSE)	MAY BE PRESENT WITH VERY SMALL DISPLACEMENTS	DISPLACEMENTS: 1's to 10's OF FEET	DISPLACEMENTS: 10's to 100's OF FEET	DISPLACEMENTS: 100's to 1000's OF FEET	DISPLACEMENTS: 1000's OF FEET TO MILES	DISPLACEMENTS: ESTIMATED INTO 10's OF MILES
METAMORPHIC FACIES				LOW GRADE	MEDIUM GRADE	HIGH GRADE
IGNEOUS ACTIVITY					MAFIC TABULAR INTRUSIONS	FELSIC PLUTONS
	1	2	3	4	5	6

The carbonate rocks in the Great Valley are often so pure that they were both quarried and deep-mined. Uses of the limestone products range from the flux-stone used in the iron and steel industry to remove silicate contaminants from blast furnaces, for the manufacture of cement, and to coat the walls of deep coal mines in order to reduce the amount of flammable coal dust in the atmosphere of the mine. Throughout much of the northern Appalachian coal basin, it is used treat and inhibit the production of acid drainage.

The Blue Ridge Physiographic Province: The Blue Ridge Physiographic Province makes up the Blue Ridge Mountains. Structurally complex, the Blue Ridge consists of highly deformed and metamorphosed pre-Cambrian and Cambrian rocks that have been intruded by basaltic and rhyolitic magmas. The province is actually an eroded *anticlinorium*, the South Mountain Anticlinorium. An anticlinorium is a broad regional anticlinal structure composed of lesser folds. In the area of the trip, the province extends from South Mountain on the west to Catoctin Mountain on the east with Middletown Valley located in between. Middletown Valley is floored by metabasalts and represents the core of the anticlinorium. To the south, erosion within the valley has exposed the billion-year old basement gneisses that underlie the structure. The basement rocks are of similar radiometric age beneath all of eastern North America! From central Ohio east to the Atlantic, the basement rocks are known as the Grenville Complex.

The Piedmont Physiographic Province: By definition, a piedmont is the plane or slope that exists at the base of a mountain. In this case, it is the sloping surface that extends eastward from the base of the Blue Ridge Mountains and disappears under the recent sediments of the Coastal Plain. The Piedmont Physiographic Province contains the most highly deformed rocks of the Appalachian region. Because of their highly deformed character, the rocks within the Piedmont succumb quite readily to chemical weathering. As a result, weathering over the past 100 million years has generated a thick *regolith* or *saprolite* that cover the rocks almost everywhere within the province. Below the thick layer of weathered material are amphibolites, schists, and ultramafic rocks known collectively as the Baltimore Complex. These rocks are interpreted to be oceanic crustal rocks that were shoved over the underlying younger rocks during a continent-continent collision that occurred 500 million years ago.

To the east, the Piedmont disappears under the Coastal Plain. The contact between the Piedmont and the Coastal Plain is referred to as the "Fall Line" because of the small waterfalls that commonly occur where streams flow from the more resistant rocks of the Piedmont onto the more easily eroded recent sediments of the Coastal Plain (refer to Figure 19). One of the best locations to view the Fall Line is at Great Falls Park just northwest of Washington, D.C. Here, the Potomac River has created a window to the Piedmont rocks which are otherwise covered by either saprolite or coastal plain sediments. Because bedrock within most of the Piedmont is rarely exposed, our trip will end at Frederick, Maryland, on the westernmost edge of the Piedmont.

The Coastal Plain Physiographic Province: Though not part of Appalachia, it is important to realize that the less consolidated materials of the coastal plain are, in reality, all the materials stripped from the Appalachians by erosion, brought east by rivers, and deposited along the eastern edge of the North American as part of its seaward extension, the continental shelf.

The Origin and Structure of the Appalachians

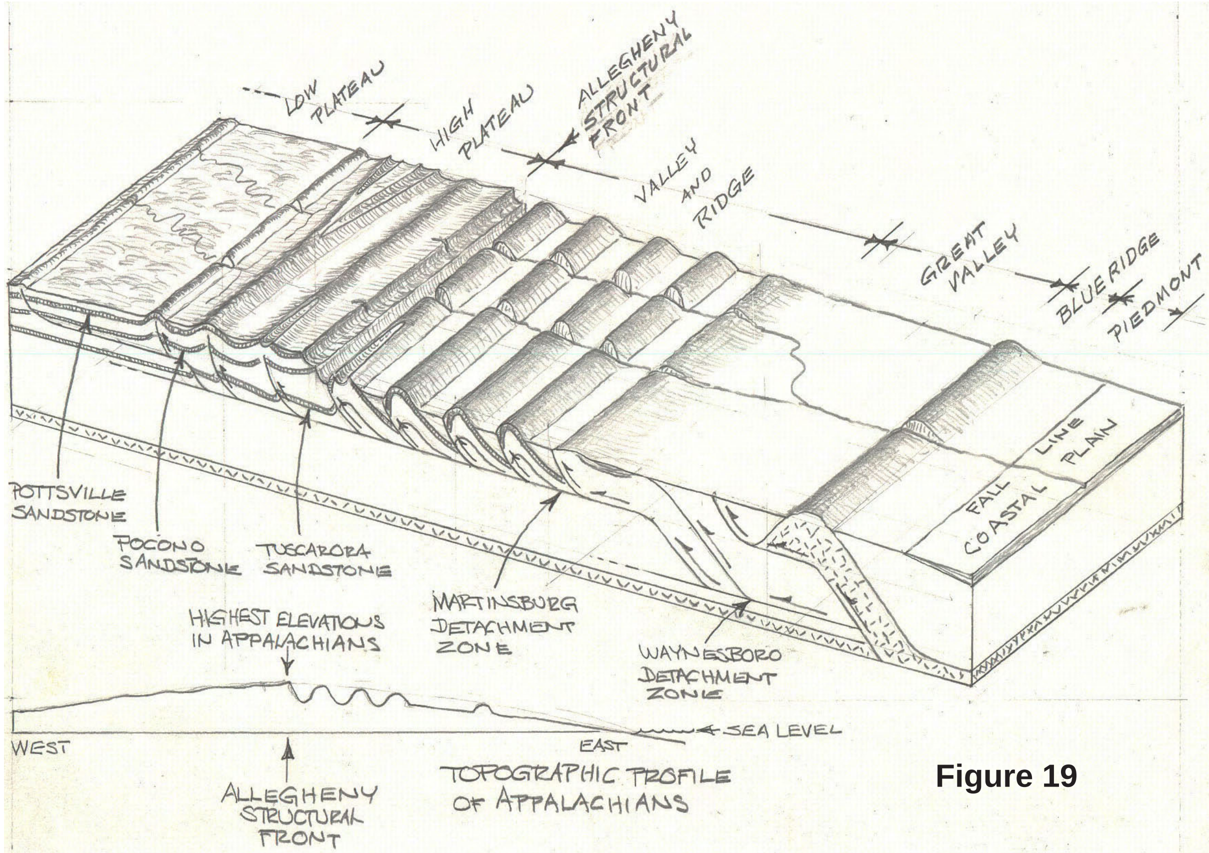


Figure 19

In order to get the most out of any field trip, it is essential to have a basic picture of the combined structure, stratigraphy, and erosional history of the area. Understanding how the structures within the area formed, although not essential, will add significantly to your overall understanding of the geology. In order to provide you with such an understanding, I must go beyond what you would learn in an introductory geology course. In the case of the Appalachians, it requires introducing you to a concept that describes the fate of sedimentary rocks that are involved in a major mountain building episode. The fact that you chose to go on this trip indicates that you are interested in understanding the geology of the Appalachians and would probably appreciate a more in-depth understanding of what you will see.

To illustrate how the structures formed, I have prepared two figures, Figure 19 which is a block diagram depicting the present topography along with the various physiographic provinces and the subsurface structures and Figure 20 (next page) that consists of five drawings that sequentially illustrate the evolution of the Appalachian structures.

The great mountains of the world were created by the collision of continents. A modern example, the Himalaya, are the result of the collision of India and Asia beginning about 45 million years ago, a collision that is not yet over as indicated by the frequency of earthquakes throughout the region combined with the fact that the Himalaya are still rising. The Himalaya, and all of the great mountains of the world including the Appalachians, are examples of *foldbelt mountains*, the name referring to the fact that a major portion of the mountain range

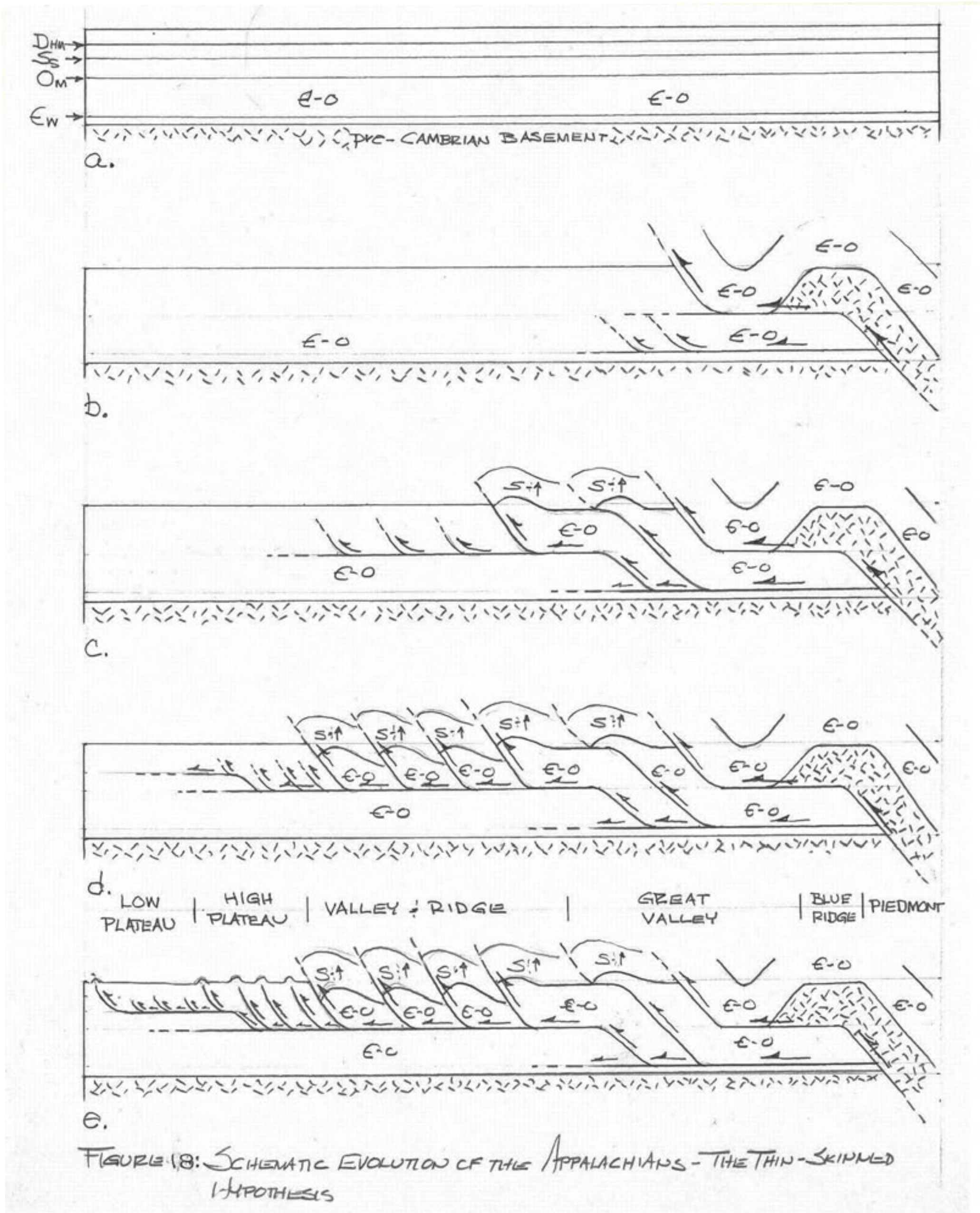

DHM
SS
OM
ЄW
Є-O
Є-O
PRE-CAMBRIAN BASEMENT
a.
b.
c.
d.
LOW PLATEAU
HIGH PLATEAU
VALLEY & RIDGE
GREAT VALLEY
BLUE RIDGE
PIEDMONT
e.
FIGURE 18: SCHEMATIC EVOLUTION OF THE APPALACHIANS - THE THIN-SKINNED HYPOTHESIS

Figure 20

consists of folded (and faulted) sedimentary rocks. Another portion of all foldbelt mountains consists of an assemblage of igneous, volcanic, and metamorphic rocks that represents the immediate collision zone between the two continents with the foldbelt portion being farther away from the zone of collision.

For many years it was taught that the folds and faults that we see at the surface throughout Appalachia extended down to and included the granitic rocks of the underlying continental crust, the so-called "*basement*". That somewhat simplistic picture changed in 1963 when data from deep seismic studies showed that not only was the basement *not* involved in the deformation, but that even the lower portion of the sedimentary rock section remained undeformed (refer to Figure 20). Compared to the massive thickness of the continental crust, the entire sedimentary layer overlying the basement is nothing more than a thin veneer. The data presented in the early 1960s showed that most of the deformation observed within the Appalachians was limited to the upper portion of the total thickness of sedimentary rock while the lower section of sediments and the underlying basement remained relatively undeformed. This observation gave rise to the new hypothesis being dubbed "*thin-skinned tectonics*".

According to the hypothesis, the forces generated by the collision caused the upper sedimentary rocks to break away, or *detach*, from the underlying sediments along the bedding of certain weak rock layers forming a *zone of detachment*. It should come as no surprise to find that detachment zones form primarily within shale formations, the weakest of all the sedimentary rocks. In addition to the inherent weakness of shale, some shale formations contained materials such as organic material, and in one case salt, that serve to "grease the slide" and promote lateral movement. Within the Appalachians, there are four rock formations that serve as zones of detachment (refer to Figure 6). From oldest to youngest, these are the Cambrian Waynesboro Formation, the Ordovician Martinsburg Formation, the Silurian Salina Formation, and the Devonian Harrel-Marcellus Formation.

Once detached from the underlying rocks, the layer of sedimentary rocks above the zone of detachment began to move in the direction of the applied forces which, in the case of the Appalachia, is westward. In order to make room for these laterally-moving masses of rocks, thrust faults *ramp* the rocks upward from the zone of detachment, stack the rocks vertically, and generate folds. All the while, the rocks below the zone of detachment remain undeformed. The process can be visualized by considering the removal of a layer of snow from a sidewalk using a plow-type snow shovel. At first, the snow can be pushed ahead with the surface of the sidewalk representing the detachment zone. In time, however, as the snow accumulates in the shovel and the snow ahead of the shovel becomes compacted, continued forward movement becomes increasingly difficult. At that point, you "ramp" the shovel upward to get rid of the accumulated snow, allowing the process to continue.

The result of the continent-continent collision that formed Pangea is schematically illustrated in Figure 20, Drawings 'b' through 'e'. The initial collision resulted in the development of a major thrust fault that originated within the basement that drove the pre-Cambrian crystalline rocks (granitic rocks and various volcanics) upward along with the overlying Cambro-Ordovician rocks. It is important to know that the Cambro-Ordovician rocks are dominantly carbonates (limestones and dolomites) (refer to the Stratigraphic Column in Figure 6). Upon arriving at the level of the Ordovician Martinsburg Formation, the compressive forces created a zone of detachment within the shale-rich Martinsburg Formation along which the rocks moved laterally. Eventually, as the resistance to further forward motion increased, another thrust fault formed that ramped the pre-Cambrian and Cambro-Ordovician rocks upward. The drawing shows only Cambro-Ordovician rocks being displaced along with the pre-Cambrian basement when, in fact, Silurian and younger aged rocks could have been (no doubt were) involved. Because all of the rocks younger than the Cambro-Ordovician age were subsequently removed by erosion, their presence is not indicated in the drawings. The pre-Cambrian and some of the basal Cambrian rocks that were involved in the initial thrusting are now exposed in the Blue Ridge Mountains with the Cambro-Ordovician rocks shown to the east in drawing “b” now being preserved as highly metamorphosed rocks within the Piedmont Province. The Cambro-Ordovician carbonate rocks shown to the west of the pre-Cambrian are now exposed in the eastern portion of the Great Valley. Note that the drawing indicates that while this major pre-Cambrian displacement was occurring, a new detachment zone was forming within the shaley Cambrian Waynesboro Formation along with an incipient ramp leading upwards to the Ordovician Martinsburg Formation.

Drawing “c” shows that the incipient detachment and ramp illustrated in Drawing “b” becomes a full-scale detachment zone with the Cambro-Ordovician rocks being thrust over the underlying Cambro-Ordovician rocks and driven westward along the Martinsburg zone of detachment. In time, the rocks leave the Martinsburg detachment zone and are ramped upward. The Cambro-Ordovician carbonate rocks involved in these detachments are now exposed in the western portion of the Great Valley. Note that Drawing “c” also indicates the westward extension of the Martinsburg zone of detachment with incipient thrusts ramping upward into the younger rocks.

Drawing “d” illustrates the ramping of the Cambro-Ordovician rocks from the Waynesboro detachment zone up to the Martinsburg zone of detachment. As the rocks move westward along the zone of detachment, several thrust faults break upward to generate the folds now seen in the Valley and Ridge. Note that Silurian and younger rocks are indicated above the Cambro-Ordovician rocks. Erosion in this area will eventually remove all rocks younger than the Devonian Harrel-Marcellus Formation which will floor the synclinal valleys. As the rocks were removed from the axial regions of the anticlines, erosion eventually reached the stratigraphic level of the Tuscarora sandstone. At this point, the extreme resistance of the Tuscarora sandstone slowed the erosion process, resulting in the formation of most of the ridges of the Appalachian Mountain Section of the Valley and Ridge Province. The ridges of the Appalachian Mountain Section are said to be *capped* by the Tuscarora sandstone. Along the summits of some of the highest ridges, the anticlines were breached as erosion cut through the resistant Tuscarora sandstone, exposing the weaker rocks below. In time, erosion formed anticlinal valleys, an excellent example of which is Germany Valley (refer to Figure 15). In addition, erosion by antecedent streams such as the Potomac successfully carved water gaps through the Tuscarora-capped ridges to allow the streams to continue their passage to the Atlantic Ocean. To the west of the Valley and Ridge, Drawing “d” shows the Martinsburg detachment continuing and faults ramping up to the next higher zone of weakness, the Salina Group. As the name implies, the Salina Group of rocks throughout the Appalachians contains salt. Being very plastic, the salt within the rocks resulting in the formation of the zone of detachment.

The last drawing illustrates the final stage of the Appalachian tectonics as thrusts ramp upward from the Martinsburg Formation and from the Salina Group to form the structures of the High Plateau section of the Unglaciated Appalachian Plateau. Because the amount of available energy decreases westward, the displacement of the faults and the amplitudes of the folds formed within the High Plateau were significantly less than those that characterize the Appalachian Mountains to the east. Even within the Unglaciated Plateau, the marked westward decline in available deformational energy resulted in the formation of High and Low Plateaus. Under the High Plateau, there was sufficient fault displacements to create anticlines with amplitudes large enough to generate significant topographic highs. You will encounter the westernmost of these anticlines, Chestnut Ridge Anticline, shortly after leaving Morgantown and will cross all of them by the time you reach the easternmost edge of the Appalachian High Plateau, the Allegheny Structural Front.

There is no positive evidence for the existence of faults under the Low Plateau. If present, they are of very small displacement. As a result, the amplitudes of folds within the Low Plateau are so low that the rocks appear perfectly horizontal, as illustrated by the rocks seen in road cuts in the vicinity of Morgantown and to the west. There is also some evidence from well records that a zone of detachment may be present within the Devonian Harrel-Marcellus Formation. Because there is little surface effect, a Harrel-Marcellus zone of detachment is not shown in Drawing 'e". The westernmost limit of detachment is where a thrust fault ramps from the Salina zone of detachment to the surface at the Burning Springs Anticline in western West Virginia. A summary of the structural relationships that exist within the Appalachians can be found in Table 1.

Road Log

A cross section from Stop #1 to the Genstar quarry at the western margin of the Piedmont Province is illustrated in Figure 21 (next page). You should keep this cross section at hand throughout the trip to help you locate yourself structurally. Because of the scale of the cross section, none of the small-scale folds you will see along the way can be shown on the drawing. The large folds, however, are indicated and should help you understand the attitude of the rocks along the course of the trip.

Unfortunately, state law prohibits non-emergency stopping along the interstate system. Along the initial West Virginia portion of the trip, I will indicate a few stops where you will be able to pull completely off the road and berm. Should you want to stop and get a better view of the land about you, take advantage of the exits, but **do not stop** along the main roadway.

Two figures that you should always have at hand as you drive are Figure 6 which contains the stratigraphic column and Figure 21 which is a cross section of the rocks you will be crossing. The stratigraphic column lists all of the rock units by age and by name and indicates the kind of rock that constitutes the unit while the cross section will allow you to determine what structure you are crossing at any point along the way.

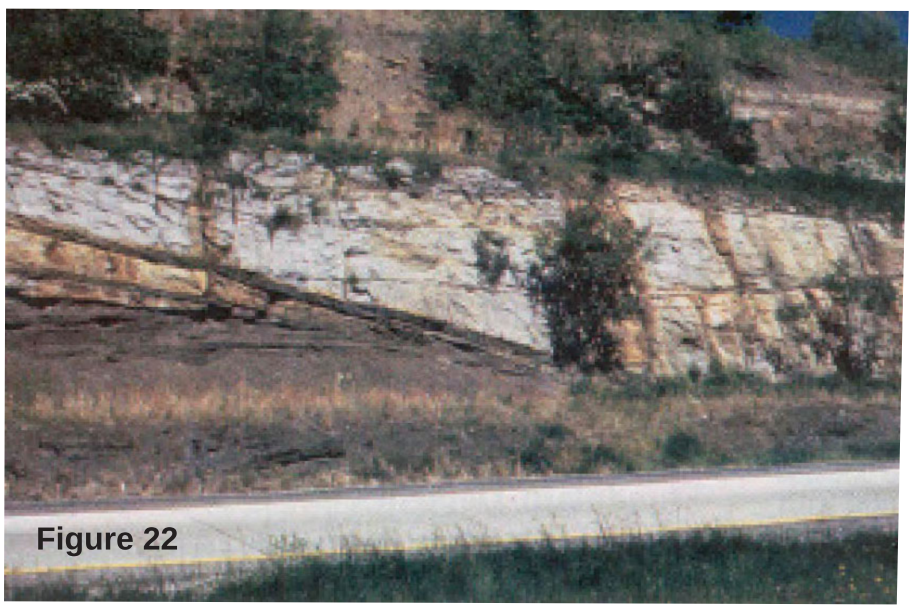
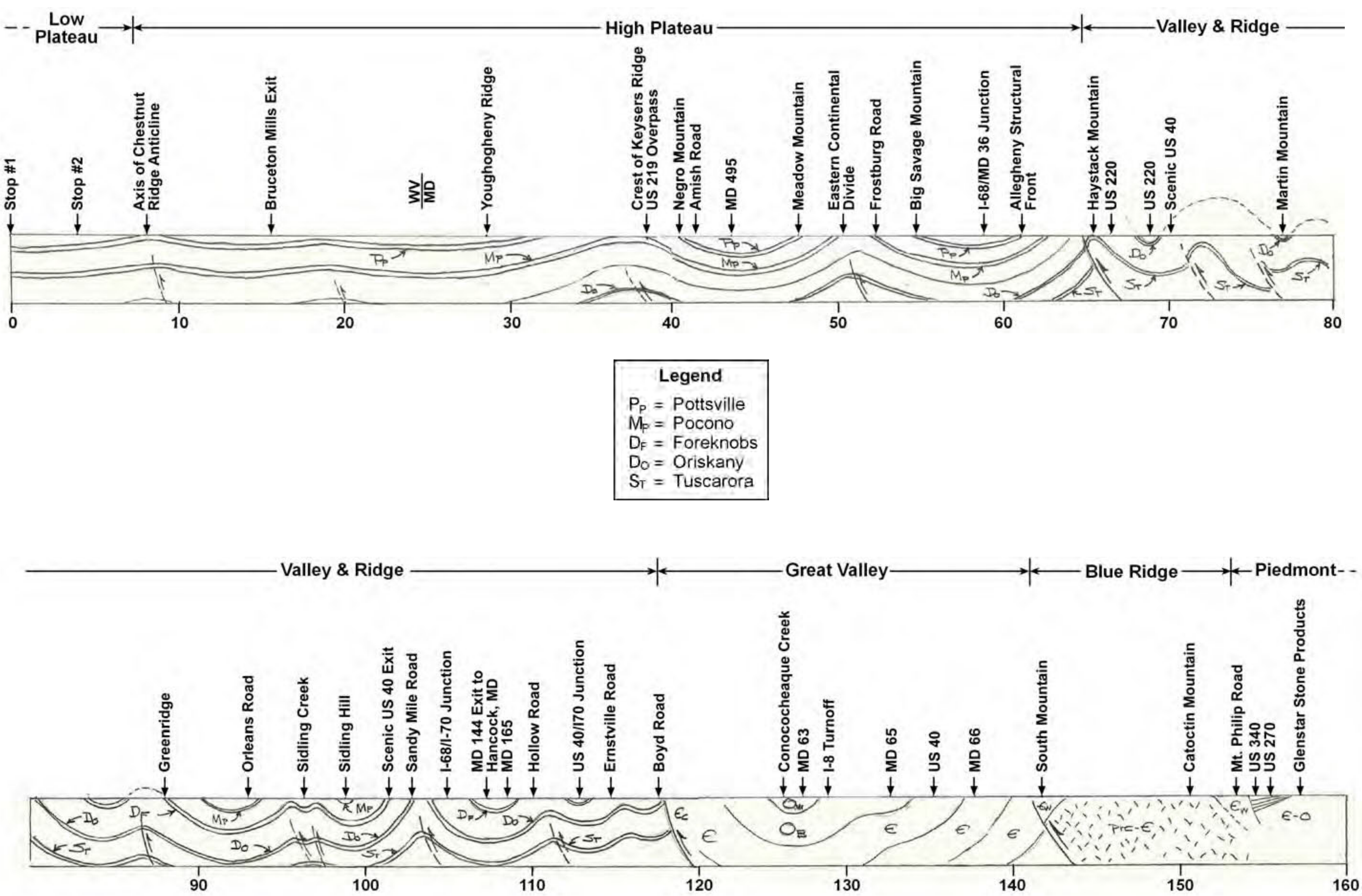


Figure 22

0.0 mile: Stop #1: Exit #7, junction of I-68 and WV Rt.857. You will begin your trip near the easternmost edge of the Appalachian Low Plateau. The rocks at the westbound exit include, from top to bottom, the Lower Sewickley sandstone, the thin (1.5') Redstone coal horizon, the Upper Pittsburgh sandstone, and the Pittsburgh coal at the base (Figure 22). Dominant crossbeds and scalloped bottoms of the sandstone beds indicate them to be fluvial (stream) channel sandstones. The Pittsburgh coal is the most important single coal bed mined in the area, accounting for 25% of the entire coal production of



Low Plateau
High Plateau
Valley & Ridge
Stop #1
Stop #2
Axis of Chestnut Ridge Anticline
Bruceton Mills Exit
WV
MD
Youghogheny Ridge
Crest of Keysers Ridge US 219 Overpass
Negro Mountain
Amish Road
MD 495
Meadow Mountain
Eastern Continental Divide
Frostburg Road
Big Savage Mountain
I-68/MD 36 Junction
Allegheny Structural Front
Haystack Mountain
US 220
US 220
Scenic US 40
Martin Mountain
0
10
20
30
40
50
60
70
80
Legend
P_P = Pottsville
M_P = Pocono
D_F = Foreknobs
D_O = Oriskany
S_T = Tuscarora
Valley & Ridge
Great Valley
Blue Ridge
Piedmont
Greenridge
Orleans Road
Sidling Creek
Sidling Hill
Scenic US 40 Exit
Sandy Mile Road
I-68/I-70 Junction
MD 144 Exit to Hancock, MD
MD 165
Hollow Road
US 40/I70 Junction
Ernstville Road
Boyd Road
Conococheaque Creek
MD 63
I-8 Turnoff
MD 65
US 40
MD 66
South Mountain
Catoctin Mountain
Mt. Philip Road
US 340
US 270
Glenstar Stone Products
90
100
110
120
130
140
150
160

Figure 21

West Virginia. The Pittsburgh coal was removed by surface operations at the southwestern corner of the intersection and it was deep-mined beneath the Glenmark Mall and the Morgantown Airport.

From this point westward, the topography is typical of the Appalachian Low Plateau being characterized by relatively low relief (the average distance between hill tops and valley floors), broad stream valleys occupied by meandering streams, low hill slopes, and rounded hill tops. Although the rocks throughout the Appalachian Low Plateau are folded, the amplitudes of the folds are so low relative to their widths that the rocks appear to be horizontal.

Set your odometer to zero as you pull onto the on-ramp to I-68 East.

2.2 mi. As you approach the western end of the Cheat Lake bridge, you are going down section as you drop into the valley of the Cheat River. Downstream, the river is dammed by a hydroelectric facility that produced Cheat Lake. Originally called Lake Lynn after the CEO of the power company at the time the lake was formed behind the dam, the locals always referred to it as Cheat Lake. After several decades, the state officially changed the name of the lake from Lake Lynn to Cheat Lake, indicating the power of public opinion.

The large outcrop that appears to your left just before reaching the bridge contains approximately 260 feet of rock from the Connelsville sandstone at the top to the shale below the thin Harlem coal at the bottom. Note that typical of the rocks in the Low Plateau, the rock layers appear horizontal. The skyline before you to the east is the crest of Chestnut Ridge Anticline, the westernmost structure of the Appalachian High Plateau.

As you cross the Cheat Lake bridge, to your right is an excellent view of the V-shaped valley cut by the Cheat River through the Chestnut Ridge Anticline.

3.2 - 3.3 mi. The sandstone that appears along the left side of the roadway after you have crossed the Cheat Lake bridge and passed Exit 10 is the Buffalo sandstone. Note once again the presence of cross beds indicating its fluvial origin.

4.0 - 4.1 mi. As you begin the ascent of the west flank of Chestnut Ridge, a broad grassy area will appear along the roadway to the right that will allow you to pull completely off the roadway and berm. This will be **Stop #2.** The rocks exposed at Stop #2 include a section from the Buffalo sandstone at the top to the Upper Freeport sandstone at the bottom with the Mahoning sandstone in the middle (Figure 23, next page). Most conspicuous is the relatively thick (13') Upper Freeport coal located below the Mahoning sandstone. The Upper Freeport is a major coal mined in the northern Appalachian Coal Basin. Unfortunately, because of its high sulfur content, it is also responsible for many of the environmental problems that have plagued the coal industry in this part of West Virginia, the most serious of which is acid mine drainage (AMD). Another thinner coal, the Brush Creek coal, can be seen at the top of the section below the Buffalo sandstone.

There are four packages of rocks within the outcrop that represent four different depositional environments. The oldest rocks (labeled #1), include the thick-bedded Upper Freeport sandstone and the overlying thin Brush Creek coals, represent a peat swamp environment. At the time these deposits were laid down, the area around what is now Morgantown was a vast coastal plane with the shoreline far to the northwest. Extensive planar swamps developed across the coastal plane. During the times when coal-forming peats were accumulating, the swamps

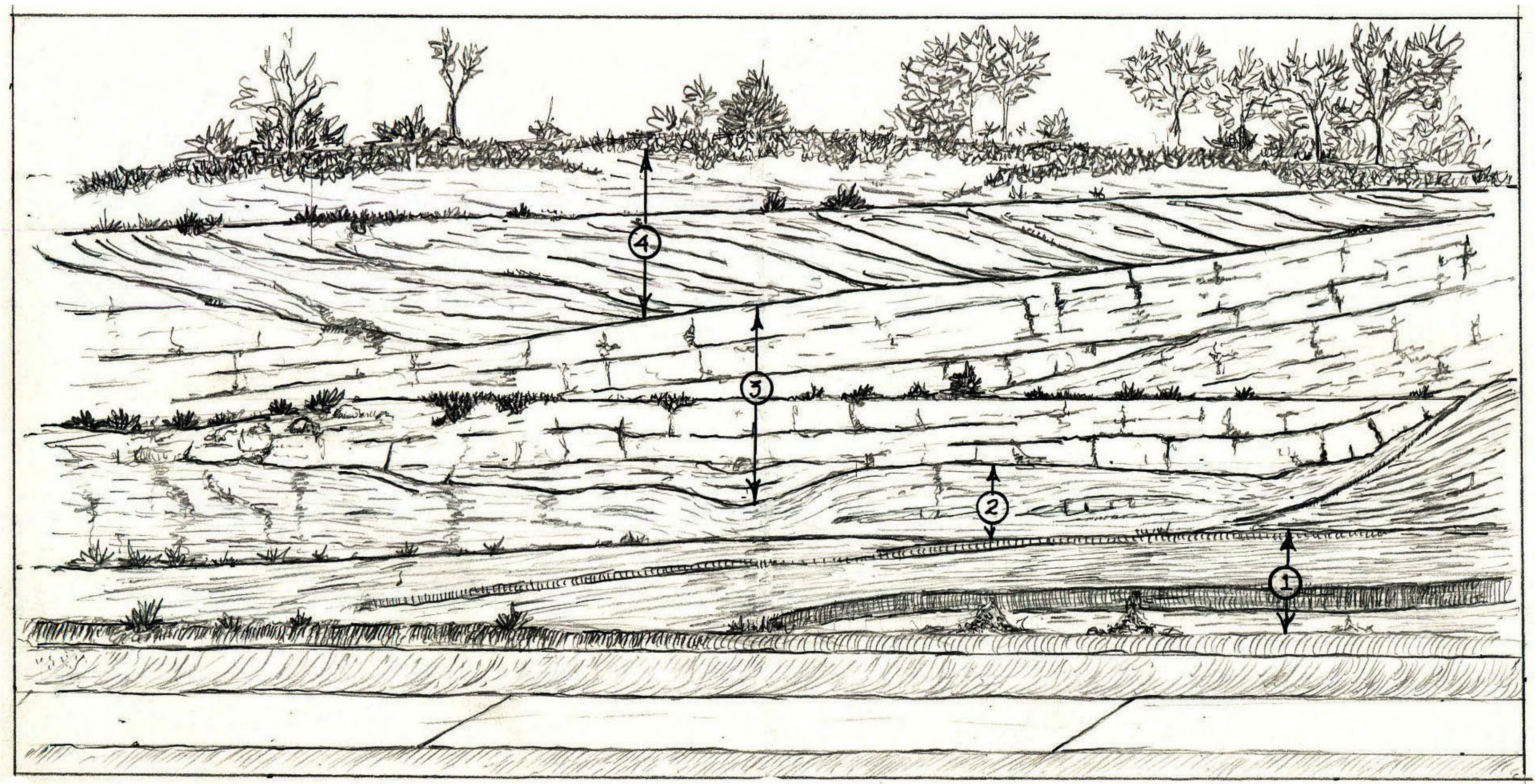


Figure 23

were far enough removed from the coastline that the waters within the swamp were totally dominated by the fresh water provided by surface runoff and groundwater and were unaffected by any marine waters. This is an important point in that the rate of organic decomposition is primarily determined by the pH of the surrounding water. Any introduction of seawater would have increased the pH of the swamp water to the point that the rate of decomposition of the plant debris would have been so high that there would not have been sufficient organic material preserved to produce a coal-forming peat. Modern studies have shown that in order for peat to accumulate in sufficient quantity to be precursor to a coal bed, the pH of the water in the swamp must be maintained below 2.5 to 3. Above pH3, the rate of organic degradation increases rapidly. In fact, the black shales that enclose the coals represent periods of time when the water pH within the swamp *was* in excess of 3, perhaps due to tidal incursion of seawater during periods of high sea levels.

The rock package labeled #2 consists of overbank materials that were deposited during flood and as the result of the breaching of the levees that bordered the rivers. Such breakouts, called **crevasse splays**, resulted in enormous volumes of detrital material being flushed into the surrounding area, destroying the swamps and burying the accumulated peat. As additional stream-deposited sediments accumulated, processes began within the buried peat that would eventually convert it to coal.

Rock package #3 consists of channel sandstones. These sandstones represent sand that accumulated in the channels of streams that now began to sweep back and forth across the coastal area, eroding much of the more fine-grained underlying overbank deposits in the process. The rock body can be clearly indicated by the scalloped bottom which represents the base of the channel as it cut into the soft sediments below. An excellent example of such scouring is the channel exposed in the center of the outcrop. Today, this package of sandstone is called the Mahoning sandstone.

The Buffalo sandstone is the final package of rocks exposed at the top of the outcrop (#4) and consists of point bar deposits laid down by the meandering streams that continued to criss -cross the area. Point-bar deposits are easily recognized by the well-developed cross bedding that dip in the direction in which the stream was meandering. This is the same sandstone that was exposed at the Cheat Lake exit ramp, which gives you an idea of the angle of dip of the western limb of the Chestnut Ridge anticline.

As you leave Stop #2, you will continue up the western limb of the Chestnut Ridge Anticline. The slope of the roadway is approximately the angle of dip of the western limb of the Chestnut Ridge Anticline. Note that the dip of the rocks on the western limb of the anticline are significantly higher than the limbs on the folds found anywhere within the Low Plateau to the west. The most conspicuous rocks along the roadway are the fluvial sandstones ranging from the Lower Freeport sandstone down section to the Lower Connequenessing sandstone. The most obvious features of these sandstones are the cross beds and the scalloped bed bottoms, all characteristic of the type of stream-deposited sandstone bodies you observed at Stop #2.

4.5 mi. Along your right, you will be able to observe several excellent examples of the mass wasting process called rock fall. Sandstone bodies underlain by easily weathered shales are particularly prone to this type of failure. Decades of freeze/thaw cycles and subsequent ice wedging pried joints open, eventually resulting in the detachment of large rocks from the original bed. As erosion of the soft underlying shales removes support from below, the rocks eventually succumb to gravity and fall to the base of the outcrop.

7.4 mi. The Coopers Rock Off-Ramp. The rock exposed along the off-ramp to Cooper's Rock is the Lower Connequenessing sandstone. If you feel you can spare the time, you can exit I-68, turn right and proceed to the overlook at Coopers Rock to experience a classic V-shaped youthful stream valley. As the region was uplifted and the Chestnut Ridge Anticline rose across the west-flowing Cheat River, the river successfully carved its channel through the rising structure, became *antecedent* to the structure, and was thereby able to continue its course to the Gulf of Mexico via the Monongahela, Ohio, and Mississippi rivers. Stream erosion has exposed the Mississippian Greenbrier limestone in the core of the water gap. Research performed in the valley suggests that the Cheat River has been lowering its channel at a rate of 58 meters per million years.

8.2 mi. The Crest of Chestnut Ridge. The rocks at this point are the Homewood sandstone underlain by coal and coally shale and the uppermost portion of the Upper Connequenessing sandstone. The vista to the east gives an excellent view of the Appalachian High Plateau. From this vantage point, one can see the marked difference in the topography as compared to the more gently rolling topography of the Low Plateau from which you have just departed. To the east, the increased relief between the ridges and valleys is apparent. The distant skyline is Meadow Mountain, about 25 miles east of your present location.

At this point, your elevation is approximately 1,900 feet (579 m); 1,000 feet (305 m) higher than at Morgantown. It is interesting to note that in the hot, muggy summers that one often experiences in Morgantown, the temperatures at crest of Chestnut Ridge average about 10 degrees cooler; a result of the rule of thumb that the temperature of the atmosphere decreases about 1 degree per 100 foot rise in elevation as a result of adiabatic cooling.

Note as you drive eastward toward the WV-MD state line how the increased amplitudes of the folds has affected both the topographic relief and the dips one observes in the rock layers exposed along the road. In the 16 miles between the crest of Chestnut Ridge and the WV-MD state line, the rocks underlying the region ranged from the Mahoning sandstone to the Homewood sandstone.

15.6 mi. Bruceton Mills Exit

20.9 mi. Note the impact of the acid mine drainage (AMD) generated by the weathering of the high sulfur coals and coal associated rocks along the median. The neutralization of the acid waters results in the precipitation of the orange-colored FeO(OH) that is responsible for the "yellowboy" coating many of the streams in the northern Appalachian coal field. Upon exposure to the atmosphere and subsequent de-hydration, the yellowboy turns red as the hydrated iron oxide is converted to hematite, Fe_2O_3.

22.0 mi. Another excellent example of the impact of acidic coal-associated rocks on the survival of vegetation can be seen along the right-hand lane. Many of the black shales associated with the coals have higher sulfur contents than the coals themselves and therefore have high acid-producing potentials. At this point, the outcrop is dominated by black shales that produce surface conditions that are too acid for any plant community to survive.

24.7 mi. The WV-MD State Line. The rocks exposed at the state line are largely the Mahoning and Upper Freeport sandstones separated by a thin outcrop of the Upper Freeport coal and the Bolivar underclay. From this point, I-68 descends into the valley of the Youghiogheny River. The rocks along the roadway are largely covered, but a few sporadic outcrops of the sandstones and shales of the Glenshaw Formation can be seen.

26.8 mi. MD 42 overpass

28.7 mi. Youghiogheny River bridge. An interesting bit of trivia is the fact that the Youghiogheny River is Maryland's only north-flowing river. It flows northward into Pennsylvania where it enters the Monongahela River which, in turn, joins the Allegheny River at "The Point" at Pittsburgh to form the Ohio River.

29.4 mi. Bear Creek

38.4 mi. Crest of Keysers Ridge and US 219 overpass. About 60 feet of fluvial sandstones of the Mississippian Purslane Formation and the underlying Rockwell Formation of Devonian-Mississippian age are exposed in the extensive exposures created by the I-68/US 219 interchange. The nearly flat lie of the rocks at Keysers Ridge is due to the fact that you have just passed the crest of the Accident Anticline. Your elevation at this point is 2880 feet (887 m).

40.3 mi. Crest of Negro Mountain. Excellent exposures of the sandstones of the Pottsville Formation can be seen. It is important to note that sandstones of the Pottsville Formation are the major ridge-formers throughout the Appalachian High Plateau. Negro Mountain is the western edge of the Casselman coal basin and syncline. The elevation at this point is 2240 feet (690 m). In Pennsylvania, the summit of Negro Mountain is the state's highest point. The axis of the Casselman Syncline will be crossed a few miles east of Negro Mountain.

41.5 mi. Amish Road Overpass. If you are interested, you might make a slight detour at this point and exit to Grantsville where there are several points of interest. Proceed east on Rt.40 and visit the Old Stone Bridge, a span on the National Road that was built in 1813 and was in use until 1933. The high arch of the span was to accommodate the C&O canal that was originally to come through the site before the advent of the steam locomotive dashed the dreams of the canal builders. Locally, this site is known as "The Narrows". The reason why the National Road, Rt. 40, and most recently I-68, are all clustered adjacent to each other at this point is because this is the best place to cross the Allegheny Mountains. It might also be pointed out for the gourmands amongst you that the small town of Grantsville is home to two well-known restaurants, Penn Alps and the Casselman Inn. Now back to I-68.

43.7 mi. MD 495 overpass. Although most of the road cuts are covered in this segment of the trip, glimpses of the Glenshaw Formation and the Bakerstown coal bed can occasionally be seen.

47.7 mi. Crest of Meadow Mountain. Road cuts on both sides of the roadway expose sandstones and shales of the Pottsville Formation. A gentle dip can be seen to the west into the synclinal axis. The elevation at this point is 2780 feet (856 m). Meadow Mountain is the western limb of the breached Deer Park Anticline, a major anticlinal structure within the High Plateau. We will see eastern limb of the structure at Big Savage Mountain. A cross section showing the structure from Meadow Mountain to Big Savage Mountain is illustrated in Figure 24.

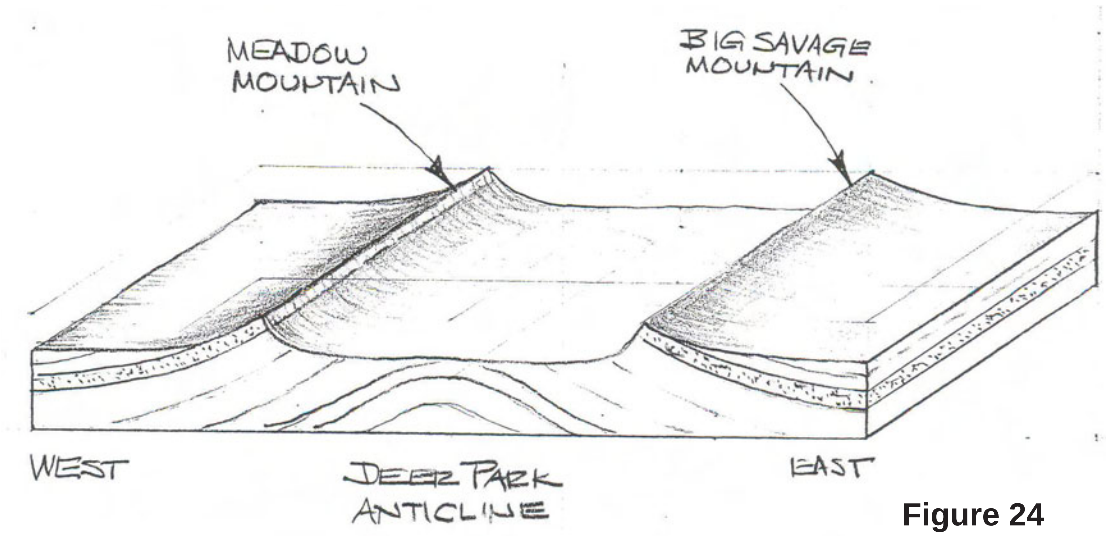


Figure 24

48.1 mi. Lower New Germany Road overpass. South of the highway is Wolf Swamp, one of several high elevation bogs and swamps in Garrett County, Maryland. These swamps date back over 15,000 years to the close of the last glacial episode when the area was much colder and was covered with periglacial tundra. Today, these wetlands contain a complex of northern plants and animals that are adapted to the colder climate.

50.4 mi. **Green Lantern Road overpass.** As indicated by the road sign, this is the **Eastern Continental Divide**. To the west of this point, all streams flow into the Gulf of Mexico while all those to the east flow into the Atlantic Ocean. The reason why the divide is so far west of the eastern edge of the Appalachian Plateau is because eastward-flowing streams have incised their channels by headward erosion into the eastern edge of the Plateau. This is another example of a breached anticline. The continental divide represents the most westerly headwaters of east-flowing streams. Approaching the Green Lantern Road overpass, the westward-dipping red sandstones and shales of the Hampshire Formation are exposed to the left. The elevation at this point is 2610 feet (803 m).

52.4 mi. Frostburg Road Overpass.

53.7 mi. MD 546 overpass. If you are more attuned to tree types, you may have observed spruce trees along the roadway over the last three or so miles. I am told by botanist friends that normally, spruce trees are limited to the more northerly conifer forests. This portion of the Appalachian Plateau in Maryland is the only place in the state with a climate severe enough to be capable of supporting these more northerly tree types.

54.8 mi. Crest of Big Savage Mountain. After traveling eastward from the MD 546 overpass, you crossed the axis of the Deer Park Anticline with the upper Foreknobs Formation exposed at its center (refer to Figure 24). Extensive exposures of sandstones of the Pottsville Formation interbedded with black shales and thin coal beds can be seen at the crest of Big Savage Mountain.

57.2 mi. Midlothian Road. As you leave Big Savage Mountain and travel toward the axis of Georges Creek Syncline, the rocks become progressively younger. The black shale talus seen along the road to the right is from the Casselman Formation of the Conemaugh Group. Further on, glimpses of the coals and black shales of the Monongahela Group can be seen. To the north of the highway is a surface mine in the Pittsburgh coal, the same coal bed you saw as you began this trip at the Pierpont exit (mile 0.0). The sandstones and shales exposed at Midlothian Road belong to the Monongahela Group. The Monongahela Group contains most of the economically valuable coals mined in the northern Appalachian Coal Basin.

58.9 mi. Junction of I 68 and MD 36. At this point you are in the axis of the Georges Creek Syncline and surrounded by the youngest rocks you will observe in the trip, the Dunkard Group. Some argument still remains as to the age of the Dunkard Group. Some geologists consider it to be basal Permian while most workers in the area consider it to be uppermost Pennsylvanian. Pollen grains could have been used to determine the age of the rocks but, during mountain building, the rocks were "cooked" and the pollen grains were destroyed. The Georges Creek Syncline contains the coals of the most easterly of Maryland's five coal basins.

61.1 mi. The Allegheny Structural Front. You have reached the easternmost edge of the Appalachian Plateau and the most dramatic change in geology anywhere in the Appalachians (Figure 25). Since leaving Morgantown, you have constantly gained in elevation. The highest elevations throughout the Appalachian region are located along the Allegheny Structural Front due to the fact that it represents the maximum elevation of the broad arch that uplifted the eastern portion of the continent beginning 60

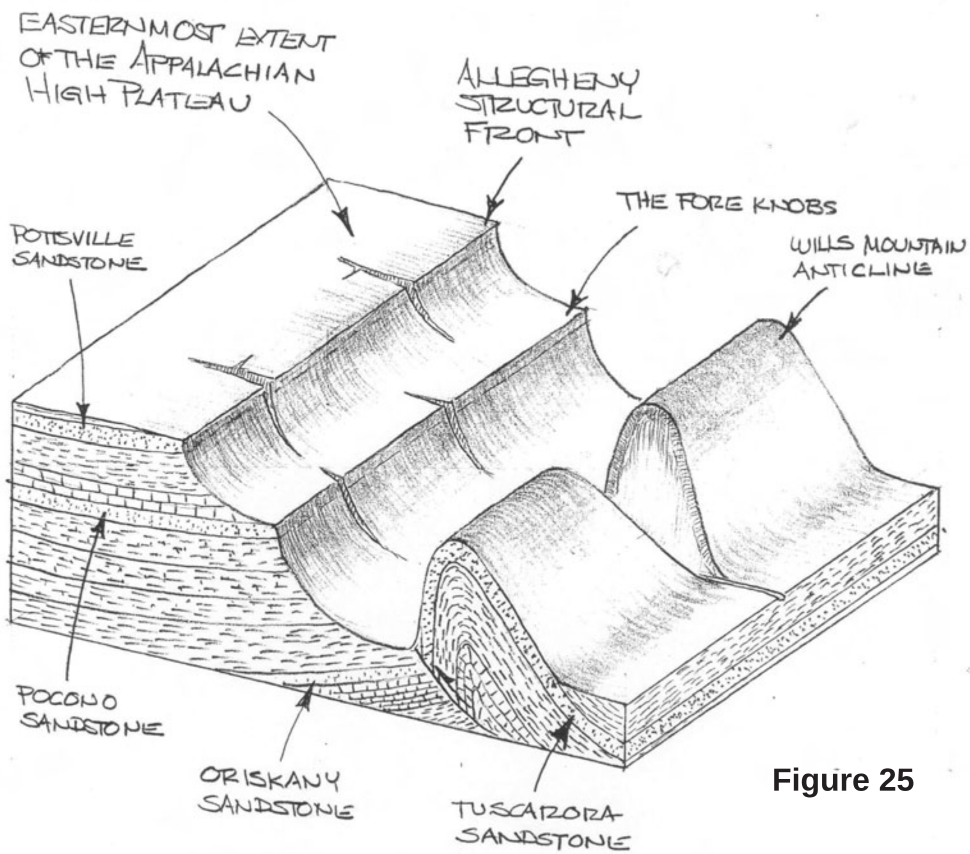


Figure 25

million years ago. In West Virginia, for example, the highest elevation, at 4,862 feet (1,482 m) is Spruce Knob, located right on the very edge of the Front. The highest point in Maryland is Backbone Mountain at an elevation of 3,360 feet (1,024 m).

Behind you stretches the Appalachian Plateau; before you lies the Appalachian Mountains Section of the Valley and Ridge Physiographic Province. While most of the rocks you observed west of the Allegheny Structural Front were of continental origin, from this point on, the rocks are dominantly marine. The rocks at the edge of the Appalachian Plateau are the massive sandstones of the Pottsville Formation. At this point you will begin the long descent down into the Valley and Ridge Province. As you make your descent, you will pass through rocks of the Mauch Chunk, Greenbrier, and Purslane Formations. Most of these rocks are easily weathered and are not well exposed. Below, however, you will encounter the gray-green laminated sandstones of the Rockwell Formation interbedded with red, greenish, or gray shales. As you approach the base of the descent, you will encounter redbeds of the Hampshire Formation and at the bottom, the largely concealed sandstones and shales of the Foreknob Formation. It is interesting to note that you *descend* from the Appalachian Plateau into the Valley and Ridge, that is, you went *down* into the mountains, not up as is most often the case. Every ridge in the Appalachian Mountains is lower in elevation than the edge of the Appalachian Plateau. Another interesting point is that as you descended from the edge of the Plateau, you traversed 100 million years of Earth history from the latest Pennsylvanian back to the Devonian.

64.0 mi. La Vale Exit. At this point we will take another short side-trip to allow you to get the true feeling of the anticlinal ridges that typify the Appalachian Mountains, most of which are highly asymmetric to overturned to the west. Leave I-68 at the La Vale exit and turn left at the intersection with MD68. Continue to Rt 40 and turn right. In about 4 miles you will turn into the Narrows, the water gap cut through Wills Mountain Anticline, the westernmost structure of the Valley and Ridge Province. As you drive into the Narrows, note the vertical outcrop to your left . This is the Tuscarora Sandstone on the western limb of the Wills Mountain Anticline. The Tuscarora Sandstone, a quartzose sandstone (quartz grains cemented by quartz), is the major ridge-former throughout the Appalachian Mountains. As you proceed, note that the Tuscarora arches up and over the valley wall and begins to descend, much more gently to the east on the eastern limb of the highly asymmetric anticlinal structure. The red rocks you see below the Tuscarora are the shales and sandstones of the basal-Silurian Juniata Formation. You may want to stop for a few minutes on the eastern side of the Narrows to get a better feeling for the structure.

After leaving the Narrows, return to La Vale on Rt.40. Continue beyond the intersection with MD68 a mile or so and turn right into the Lowe's parking lot where you can view not only an exposure of the Devonian Brallier Formation but also an excellent view of the Narrows water gap. Return to I-68.

65.2 mi. Crest of Haystack Mountain. After returning to I-68, the roadway makes its way up the western flank of the Wills Mountain Anticline. To the south, this same structure is breached to create Germany Valley (refer to Figure 15). The Tuscarora sandstone is exposed along the right-hand lane. At the top of the grade, you are on the axis of the Wills Mountain Anticline capped by the Tuscarora sandstone. In Maryland, the ridge is called Haystack Mountain while in Pennsylvania and West Virginia, it is known as Wills Mountain. This multiplicity of names for topographic features and rock units is common in geologic literature. In the case of the names assigned to rock units, for example, the differences are largely due to the fact that rock units were named in different areas before it was discovered that they were the same. In other states, for example, the Tuscarora Sandstone is called the Medina while in others, the Shawangunk. Note that as you drive eastward, the Tuscarora sandstone can be see dipping to the east as you descend the eastern limb of the Wills Mountain Anticline toward the axis of the Evitts Creek Syncline.

66.5 mi. US 220 overpass. As you descend from Haystack Mountain into the city of Cumberland, Maryland, the tan and rust-colored weathered shales of the Rose Hill Formation immediately overlying the Tuscarora sandstone can be seen along the east-bound lane with beds dipping to the southeast as you travel toward the axis of the Evitts Creek Syncline.

Cumberland is a city of approximately 24,000 inhabitants and was founded about 250 years ago on the site of a colonial fort guarding the National Road at mile 41.5 (Rt.40 and the Amish Road overpass). I-68 is elevated through town and gives excellent views of Knobbly Mountain to the south, Shriver Ridge to the north, and the Potomac River along the roadway to the right. Beyond Cumberland, you will observe relatively poor exposures of Mahantango shales and the overlying Brallier Formation. Cumberland was the westernmost end of the C&O canal which passed into history with the advent of the railroads.

68.9 mi. US 220 overpass (again). At this point, you are crossing the axis of the Evitts Creek Syncline. As you drove eastward from Cumberland, outcrops of the Devonian Brallier and Harrell formations were seen. The Brallier Formation consists primarily of rust-colored siltstones and shales while the Harrell formation consists of dark gray to black shales. Eastward beyond the US 220 overpass, the dark-gray siltstones and shales of the Mahantango Formation are encountered as you continue down-section. Low cuts in the eastbound lane expose the Keyser limestone with the Tonoloway limestone exposed on both sides of the road as you approach the Scenic US 40 overpass.

70.2 mi. Scenic US 40 overpass.

70.3 mi. East of Scenic US 40 overpass, the greenish-gray shales of the Rose Hill Formation appear in the next high road cut with moderate to steep westerly dips as you travel up-section through the west limb of the approaching Evitts Creek Anticline. At the far end of the cut, the Rose Hill shales are overlain by the rust-brown weathering Keefer sandstone. For the next mile or so, as you cross the nose of the Evitts Creek Anticline, the road cuts are dominated by the Rose Hill shales, some of them showing the overlying Keefer sandstone. Note the reversal in the dip of the beds as you cross the axis of the anticline. As you approach the Pleasant Valley Road overpass, the gray shales and thin limestones of the McKenzie Formation and the shales and limestones of the overlying Wills Creek Formation appear along the roadway as you continue up-section on the eastern limb of the Evitts Creek Anticline

74.1 mi. Pleasant Valley Road Overpass. Rocky Gap State Park is to the left.

76.8 mi. **Crest of Martin Mountain.** Approaching the crest of Martin Mountain, the pale-gray Tonoloway limestone is exposed in the east-bound lane. Rock Gap Lake can be seen to the right. Martin Mountain is an example of a synclinal ridge. The mountain is capped by the Oriskany sandstone. The Oriskany sandstone is important as a ridge-former throughout the Appalachian Mountains and also historically in that it has produced more gas and oil throughout the Appalachians than any other single rock unit.

We will take a very short detour at this point. Leave I-68 at Exit 52 and turn right on MD 144. Within less than a tenth of a mile, an excellent example of a symmetrical anticlinal structure in the Tonoloway limestone appears to your left. If you want to stop and take a closer look, immediately ahead there is an old scenic pull-off where you can park.

Continue on MD 144 toward Flintstone. To the left is a quarry in the Tonoloway limestone. The structure is a subsidiary fold on the east flank of Martin Mountain. East of the quarry, the trip crosses an anticlinal axis and as a result, the exposed rocks become increasingly younger as you drive toward the synclinal axis. Re-enter I-68 at Flintstone.

80.4 mi. Warrior Mountain. The roadway transects Warrior Mountain through a water gap eroded by Flintstone Creek. Warrior Mountain is capped by the Oriskany sandstone. In the water gap, the most conspicuous rocks are the Keyser limestones. At the top of the cut to the left, the large rock outcrop is an ancient coral reef.

83.4 mi. Crest of Polish Mountain. Polish Mountain is a synclinal mountain ridge with the topographic summit offset to the west of the axis of the Polish Mountain Syncline. From Warrior Mountain, you traveled up-section as you approached the axis of the syncline through the gray siltstones and limy siltstones of the Needmore Formation, through the dark shales and siltstones of the Mahantango Formation to the rust-colored siltstones and shales of the Brallier Formation and the Foreknobs Formation that caps the ridge. The highway grade on the west side of the ridge lies mostly on fill and outcrops are poor. The elevation at this point is 1246 feet (379 m). As you descend from Polish Mountain, the next 4 or 5 miles you will cross a broad belt underlain by rocks of the Brallier Formation, the rocks you saw in Lowe's parking lot. Although the overall structure is anticlinal, many smaller folds can be seen in the outcrops. In general, in the Valley and Ridge, the valleys are formed by shales and the ridges are capped by sandstones.

86.9 mi. Fifteen Mile Creek Bridge.

88.0 mi. Crest of Green Ridge. Traveling eastward from Fifteen Mile Creek, you will go up-section through the Brallier Formation to the Foreknobs Formation that caps the ridge. Deep road cuts on the east flank of Green Ridge shows the transition between the redbeds of the Hampshire Formation and the tan to gray sandstones and shales of the Foreknobs Formation. The elevation of Green Ridge is 1040 feet (316 m).

93.0 mi. Orleans Road overpass. Although poorly exposed, the rocks in this portion of the trip belong to the Hampshire Formation. Note the change in the dip of the rocks as you cross a synclinal axis. At this point you get an excellent view of the Sidling Hill gap along the eastern skyline. Nearly all of the rocks you observe along the roadway belong to the Hampshire Formation.

96.3 mi. Sideling Hill Creek Bridge. As you approach the Sideling Creek Syncline, the rocks will get progressively younger. The rocks underlying the bridge are those of the Hampshire Formation. Note the eastward dip.

98.8 mi. Crest of Sideling Hill. Without doubt, this is one of the most well-known and photographed outcrops in the Appalachians (refer to Figure 16a & 16b). When first opened, so many people were breaking the law by stopping to look at the structure that the State of Maryland finally decided to build a visitor center to accommodate the interested public. The ridge is a perfect example of a resistant caprock mountain along the axis of a synclinal structure. The excavation removed nearly 5 million cubic yards of material, exposing 850 feet of rocks belonging to the Purslane and Rockwell members of the Pocono Formation with the Purslane member capping the ridge. Although the exhibit center is no longer open, the overall geology of the area and is certainly worth a stop. Heading east, pull off into the parking area and walk across the bridge spanning I-68. If you approach from the east, you can exit I-68 directly into the visitor's center.

101.4 mi. Exit to Scenic US 40. The road to the left exposes shales and siltstones of the Mahantango Formation. Several exposures of the underlying Marcellus and Needmore shales have also been present along the road, but because they weather quite rapidly, the exposures are poor and probably can not be seen.

102.8 mi. Sandy Mile Road overpass. On the right are two abandoned quarries, one in the limestones of the Keyser Formation and the other in the Oriskany sandstone which caps the ridge. The fact that you have gone down stratigraphically over the past few miles indicates that you are approaching the axis of an anticline. Although the exposures are poor, the observed sandstone beds are probably those of the Keefer Formation with the anticlinal axis in the immediate area. The fact that I-68 ascends a long grade through the Wills Creek Formation approximately a half mile further east indicates that the anticlinal axis has been passed and that you are going up stratigraphically. The outcrops of east-dipping rocks along the roadway continue to become younger to the east as I-68 crosses outcrops of the Tonoloway limestone, limestones of the Keyser and Helderberg Formations and the Oriskany sandstone.

104.9 mi. I-68 separates from I-70

102.8 mi. Exit to MD 522. This might be a good point for a combination rest and food stop. Leave I-68 and exit into Hancock, MD. There are a number of good eating places along the main street. In addition, while you are in town, you might want to visit the C&O Canal visitors center that is just off the main drag to the right. After all needs have been satisfied, continue through town and re-enter I-68 (east) at the fruit and vegetable stand.

112.8 mi. US 40 and I-70 merge

114.7 mi. Ernstville Road overpass.

117.6 mi. Boyd Road overpass. Between the Boyd Road overpass and the MD 68 overpass, the roadway passes around the nose of Boyd Mountain. Boyd Mountain is capped by the Oriskany sandstone which can be seen in the cliffs just below the crest of the ridge. Boyd Mountain is the site of another major fault that places the Cambrian Conococheaque limestone against the Devonian Oriskany sandstone, a displacement of about 8,000 feet (2432 m). At this point you have left the Appalachian Mountain Section of the Valley and Ridge Physiographic Province behind and have entered the Great Valley Section of the Valley and Ridge Physiographic Province.

121.8 mi. MD 68 overpass. Karst ridges of the Cambrian Conococheaque limestone can be seen in the adjacent pastures. Note the appearance of the cedar trees. Being lovers of alkaline soils, cedars are a sure sign that the underlying bedrock is limestone. In the next few miles, you will observe excellent exposures of the Ordovician Rockdale Run Formation, the Ordovician Pines Station dolomite, the Ordovician St.Paul limestone, the Ordovician Chambersburg limestone and the Ordovician Martinsburg Formation as you approach the synclinal axis near Conococheaque Creek.

126.3 mi. Conococheaque Creek. The creek flows through a series of tight meanders as it passes north to south along the outcrop belt of the Ordovician Martinsburg Formation.

127.5 mi. MD 63 underpass. The exposures along the road are the dark-gray siltstones and shales of the Ordovician Martinsburg Formation.

129.0 mi. I-81 turnoff. Outcrops in the pastures to the right are limestones belonging to the Ordovician Rockdale Run Formation.

132.7 mi. MD 65 underpass. Outcrops of the Ordovician Stonehenge limestone can be seen among the trees to the left. The low ridges to the left are capped by the Ordovician Stonehenge limestones. At this point, the Blue Ridge Mountains form the eastern skyline.

135.3 mi. US 40 overpass. Small outcrops of the Conococheaque limestone and Tomstown limestones can be seen in the fields. Typical of areas underlain by limestones, the region exhibits the sinkholes typical of karst topography (see Figure 18). Also common to regions underlain by extensive limestones, the soils are quite thin and are stained red by the iron contained in the insoluble portions of the limestones that is released as the calcareous materials dissolve. One can only imagine Civil War soldiers, both Blue and Gray alike, passing this way and thinking that these rocks could provide a bit of protection if they were fired upon.

137.8 mi. MD 66 overpass. Poor outcrops of the Cambrian Elbrook limestone can be seen in the pastures to the north of the highway. At this point in your trip, you are approaching the easternmost limit of the Great Valley Section. South Mountain, the first prominent ridge of the Blue Ridge Physiographic Province forms the eastern skyline.

141.8 mi. The crest of South Mountain. South Mountain is one of the ridges of the Blue Ridge Physiographic Province and is held up along most of its length by the west-dipping Cambrian Weverton Quartzite; unfortunately it is cut out by faulting at the location of the I-70 crossing. The spectacular view to the east from this vantage point is the Middletown Valley between South Mountain and Catoctin Mountain. The valley is floored by the metabasalts of the pre-Cambrian Catoctin Formation, excellent exposures of which will be seen at Catoctin Mountain. These rocks represent the core of a gigantic fold called the South Mountain Anticlinorium. An anticlinorium is a very large anticlinal structure within which the rocks have been subjected to complex folding and faulting. The walking bridge that crosses the roadway carries the Appalachian Trail.

144.6 mi. The outcrops along the right-hand lane are greenstones formed by the metamorphism of the basalts. When wet, the rocks are dark-green in color due to the mineral content, especially the presence of chlorite.

150.7 mi. The crest of Catoctin Mountain. Another of the ridges of the Blue Ridge Physiographic Province, Catoctin Mountain is capped by resistant metabasalts of the pre-Cambrian Catoctin Formation, a thick sequence of basaltic and rhyolitic lavas extruded during the late pre-Cambrian and metamorphosed to the observed foliated greenstones during an ancient continent-continent collision. The white veins and pods are quartz while the green ones are epidote. As you drive down the eastern slopes of Catoctin Mountain, outcrops of the Cambrian Weverton Formation are common with a high road cut along the east bound lane showing several outcrops and much quartzite rubble.

Rt. 40 exit: At this point, you have left the Blue Ridge Province and entered the Piedmont. The Rt. 40 exit is an excellent geologic route despite the very heavy traffic day and night. In the 1970s, this area was not yet overrun by development. Carbonates and the Triassic deposits were to be seen everywhere. Now you can stop to eat and buy most anything but the rock outcrops are conspicuous by their absence. We urge you to travel east-bound along the four-lane divided highway and pull into the parking lot of either the Pep Boys or Pier One. The rocks exposed here are real and in place. These are the coarse-grained Triassic **diamicts** (pebble- and cobble-sized sub-angular carbonate fragments in a matrix that was mud during the Triassic). The rocks show “bedding” planes that dip! Packages of rock and mud flowed off the highlands to the west. Look back to the Blue Ridge and imagine much higher mountains towering above and capped by Cambrian and Ordovician carbonates over 200 million years ago! Debris flows, perhaps triggered by heavy rains and snow melt and/or earthquakes flowed down the steep slopes into the Triassic Basins that formed by tensional forces that were set into play as North America broke away from the super-continent of Pangea 200 million years ago (refer to Figure 2). As the basins continued to form, thousands upon thousands of feet of sediment accumulated! From time-to-time, lakes formed in the basins and dinosaurs came down to drink only to leave their footprints in the mud. Not far away, in Virginia, over 10,000 feet (3040 m) of sediment accumulated in such an environment.

153.5 mi. Mt. Philip Road overpass. Between Mt. Philip Road and the US 340 underpass, the roadway crosses the Triassic red sandstones, limestones, conglomerates, and igneous intrusions which typically are not seen in outcrop but whose presence can be seen in the bright red color they impart to the soils. This is also the location of a concealed fault that establishes the contact between the Triassic rocks and the Cambrian Araby Formation. During the Triassic, as the newly formed continents were being rifted from the super-continent Pangea, tensional forces generated normal faults that resulted in the formation of basins which were rapidly filled by erosion of the adjacent highlands

(Figure 26). Evidence that the sediments were rapidly transported, deposited, and buried is indicated by the presence of arkoses, feldspar-rich sandstones. Had the sediments not been rapidly buried, the feldspars would have been decomposed to clay minerals. In several areas, especially Pennsylvania, Virginia, and the Connecticut Valley, sediment surfaces have preserved the tracks of dinosaurs that roamed the area during the Triassic.

154.6 mi. US 340 underpass.

155.5 mi. US 270 underpass

157.3 mi. Genstar Stone Products quarry. The quarry operates in the Cambro-Ordovician Grove limestone. What is often sold as "Frederick Marble" when polished or "Frederick Carbonates" as aggregate is known to geologists as "inlier". Although undoubtedly correlative to the Cambrian-Ordovician carbonates west of the Blue Ridge, the lack of fossils has made it too problematic to correlate these rocks directly to the rock names west of the Blue Ridge.

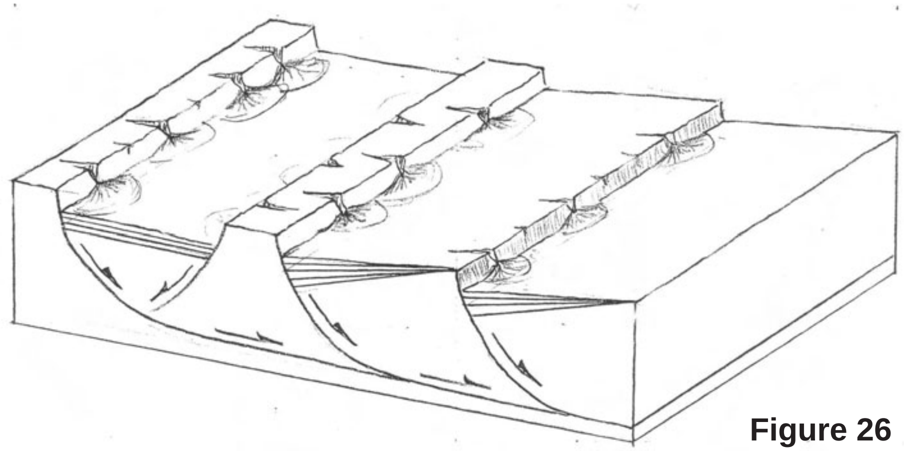


Figure 26

Frederick, Maryland. A few miles east of Frederick, Maryland, the rocks become covered by regolith and soil, obscuring any possibility of rock outcrops. For this reason, the trip will terminate in Frederick.

Some Commonly Used Terms

Allegheny Structural Front - the divide between the Appalachian Plateau and the Valley and Ridge Physiographic Provinces
Appalachian Plateau - that part of the Appalachians underlain by symmetrically folded sedimentary rocks
acid mine drainage - the acidic solution produced when coal and coal-associated rocks are exposed to the atmosphere
antecedent - refers to a stream that was able to maintain its course during uplift and successfully cuts through a topographic high such as a ridge
anticline - a convex upward fold
anticlinorium - a regional anticline consisting of smaller folds
axial plane - an imaginary plane oriented parallel to the trend of a fold that attempts to divide the cross-section of a fold into two equal halves
asymmetric fold - a fold whose axial plane is inclined and whose limbs dip in opposite directions
bed - an individual layer of sedimentary rock
bedding - the arrangement of all sedimentary rocks in beds of varying thickness and kinds
breached anticline - an anticline whose crest has been deeply eroded so that the axis is flanked by inward-facing scarps
continental divide - a drainage divide that separates streams flowing in opposite directions on a continent, usually to different oceans
dendritic drainage pattern - a stream pattern resembling the branching veins in a leaf that develops in areas underlain by horizontally layered or uniformly homogenous rocks
dip - the angle made between a planar surface such as a bed or a fault and the horizontal
diamict - a rock consisting of sand- and larger-sized particles contained within a mud matrix
fault - a rock fracture along which there has been movement
fold - a bend in a planar feature such as a bed, usually resulting from compressional forces
fold axis - the line generated by the intersection of the axial plane of a fold and the horizontal
formation - a body of rock identified by its lithology and stratigraphic position
gneiss - the most abundant metamorphic rock, characterized by the interlayering of dark- and light-colored minerals
headward erosion - the lengthening and cutting upstream of a young valley by a youthful stream
joint - a rock fracture along which there is no measurable movement
karst topography - the topography that forms by the dissolution of underlying rocks such as limestone and gypsum characterized by sinkholes, caves, and underground drainage
limestone - a sedimentary rock composed primarily of carbonate minerals, usually calcite
limb - that part of a fold between adjacent anticlinal and synclinal axes
normal fault - a fault created by tensional forces that results in an extension of Earth’s crust
overturned fold - a fold with limbs dipping in the same direction
physiographic province - a region with a common geologic structure, climate, and geomorphic history
plateau - any reasonably flat area of considerable extent underlain by essentially horizontal rock layers
recumbent fold - a fold with an axial plane that approaches the horizontal

regolith - the layer of weathering products accumulated above bedrock
relief - within a region, the average distance between the hilltops and valley floors
reverse (or thrust) fault - a fault created by compressive forces that results in a shortening of Earth's crust
sandstone - a sedimentary rock composed primarily of sand-sized quartz grains
saprolite - a clay-rich, thoroughly decomposed rock of any kind that formed in place by chemical weathering
schist - a strongly layered metamorphic rock
shale - a finely layered sedimentary rock composed primarily of clay minerals
siltstone - a sedimentary rock intermediate in composition between a sandstone and a shale
sinkhole - a circular or elliptical surface depression that characterizes areas of karst topography
stratum - an individual layer (bed) of sedimentary rock
strata - the plural of stratum
stratigraphy - (a) the study of sedimentary rocks, (b) the arrangement of strata as to position and chronologic order
strike - the direction of a line made by the intersection of a planar surface such as a bed or a fault and the horizontal
symmetrical folds - folds whose axial planes are vertical and whose limbs dip away from the axis in opposite directions at equal angles of dip
syncline - a convex downward fold
trellis drainage - the pattern made by streams that develop in a region characterized by parallel ridges and valleys
ultramafic - refers to igneous rocks composed almost entirely of olivine
water gap - a pass through a mountain ridge through which a stream flows
yellowboy - the precipitated oxy-hydroxides of iron that collect in AMD-impacted streams as the acidity of the water is reduced by treatment or dilution

MAJOR RIDGE-FORMING SANDSTONES

Pottsville Sandstones (basal Pennsylvanian)- most topographic highs within the Appalachian Plateau

Pocono Sandstones (basal Mississippian) - exposed along the Allegheny Structural Front in the Fore Knobs

Oriskany Sandstone (lower Devonian) - forms many minor ridges within the Valley and Ridge

Tuscarora Sandstone (basal Silurian) - the major ridge-former in the Valley and Ridge Province

MAJOR RED-COLORED ROCKS

Mauch Chunk (upper Mississippian) - widely exposed in Appalachian High Plateau and along the Allegheny Structural Front

Hampshire Formation (upper Devonian) - widely exposed within the Valley and Ridge

Juniata Formation (upper Ordovician) - exposed in Valley and Ridge water gaps below the Tuscarora Sandstone