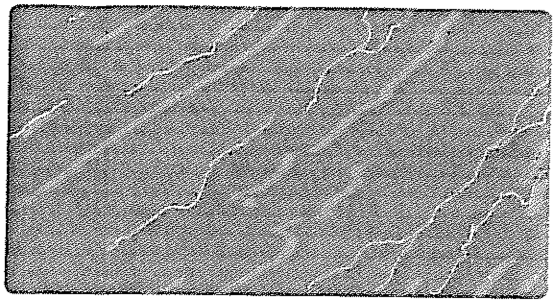
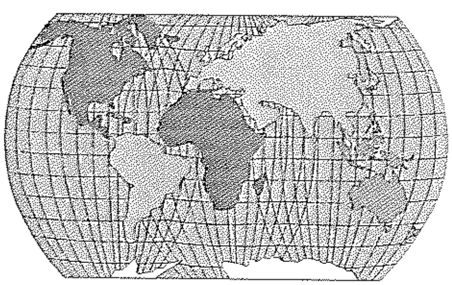
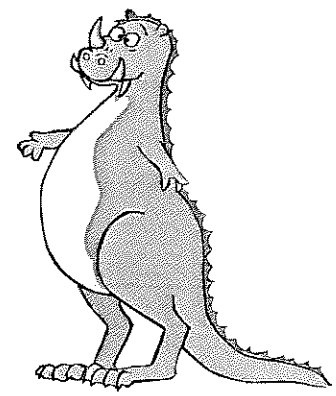
Geology and Mineral Resources of the Gettysburg, Adams County, Pennsylvania Area



Field Trip designed for Harrisburg Area Community College - Gettysburg Campus





by Jeri L. Jones, Jones Geological Services
and G. Patrick Bowling, P.G
September 29, 2001.

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INTRODUCTION

Welcome to the fall geologic excursion sponsored by HACC-Gettysburg Campus. It is hoped that your day traveling in the vicinity of Gettysburg will be knowledgeable and interesting. What the co-leaders put together for you today are stops that not only are judged as "cool" places to visit, but reach to various aspects of the earth sciences. By the time we return to the campus today, hopefully you will have gained an understanding on the diversity of the earth sciences, and the role a geologist plays in interpreting the geology as well as how to utilize our mineral resources. Most importantly, we hope that a better understanding of the area's geology will be understood, and the processes that they have encountered during the past and in the present. Remember, when you speak of Earth's history, today we are only looking at a very small piece of a large jigsaw puzzle.

ITINERARY AND TOPICS

Stop 1	9:25 - 10:25 am	Valley Quarry - Gettysburg
Stop 2	10:40 - 11:00 am	Gettysburg Municipal Authority Well #6
Stop 3	11:10 - 11:55 am	CSX Railroad Cut
	12:05 - 12:35 pm	Lunch - Gettysburg Recreational Park
Stop 4	12:55 - 1:25 pm	Valley Quarry - Fairfield
Stop 5	1:45 - 2:05 pm	West Confederate Ave. Observation Tower Parking Lot
Stop 6	2:15 - 2:35 pm	South Confederate Ave. Bridge over Plum Run
Stop 7	2:40 - 3:25 pm	Little Round Top (Optional Walk to the Maine Monument)

ACKNOWLEDGMENTS

Any field trip back into time involving "on-site" inspection cannot be conducted unless we have the cooperation of the landowners. We want to thank Valley Quarries - Gettysburg and Fairfield plants, for their cooperation in preparing for the trip as well as being on site with us during the tour. Quality Inn Larson's has allowed us to use their parking lot and land to access the Seminary Ridge diabase dike. Officials of CSX Railroad granted us permission to inspect the railroad cut. We finally want to thank the bus driver of Gettysburg Tours who sometimes has the challenge to fit the bus into spaces that seem impossible. Undoubtedly, we need to thank you, the participants in registering for this tour. We hope you enjoy this trip as much as we enjoy presenting the information to you.

ABOUT THE CO-LEADERS

JERI JONES - A native of York, Pennsylvania, Jeri received his B.S. in Geoarchaeology from Catawba College in Salisbury, North Carolina. He has been employed by the York County Parks for 22 years where he conducts a number of geologic programs. His interest in local geology has led to many research projects. His favorite topics include the Dillsburg Iron Mines, gold prospecting, iron mining history and earthquakes. Today he represents his other business, Jones Geological Services, where he conducts research projects and conducts educational programs to civic and scout groups. He has also written numerous articles on local geology including "Whispering Hills" in 1989 and "Gold in southeastern Pennsylvania" due to be released in late fall of 2001. He has also narrated a three-part video series known as "TimeWalk" which has been distributed to area schools and shown on cable television.

G. PATRICK BOWLING, P.G. - Having grown up in Gettysburg with a father who was keenly interested in the history of the battle, Pat was fascinated by Devil's Den and stories of dinosaur footprints on a battlefield bridge. As a result, he was drawn to the study of geology and received his B.S. from the University of Pittsburgh in 1981. In 1987, he received an M.S. in geology from the New Mexico Institute of Mining and Technology in Socorro, New Mexico where he focused on geochemistry and crustal evolution. Since 1988, he has been employed by the Pennsylvania Department of Environmental Protection as a ground-water geologist where he currently works on drinking water source protection efforts including public education and outreach activities. He is a licensed professional geologist in Pennsylvania and is a member of the Geological Society of America. After stints in suburban Philadelphia and East Berlin, PA, he now resides in historic Gettysburg once again.

LARRY EISENBERGER - A native and resident of Hanover, Pennsylvania, Larry started to collect minerals in 1980. Since that time, his interest concentrates on "micromounting," collecting and studying only those crystals observed under a microscope. Today, his collection has grown to over 14,000+ specimens totaling 2,100 different mineral species. His collection is one of the best "micro" displays for Pennsylvania. Larry's dedication to his hobby guarantees that he is out nearly every weekend collecting one of his favorite locality or checking out a new location. Several of his favorite locations include Valley Quarry in Gettysburg (in which you will meet him), Gap Nickel Mine in Lancaster County, Grace Mine in Berks County, and Codorus Stone quarry in York County. He has written several articles about his favorite localities. He is currently working on a detailed mineral article concerning Valley Quarry in Gettysburg which will be published.

FLOYD JONES, ESQ. - An older brother of Jeri, Floyd joins us today to provide the history of the Battle of Gettysburg during the afternoon stops. His interest in the Civil War was sparked by his father who studied the famous war as a hobby. Floyd attended Catawba College in Salisbury, North Carolina where he majored in history. He attended University of Pittsburgh Law School before returning to York to pursue his law career. Floyd has toured every Civil War battle ground and brings with him today a wealth of information about the Battle of Gettysburg.

TOPOGRAPHY OF ADAMS COUNTY

Topography is the "lay of the land" or landforms. In this part of the United States, the landforms are greatly influenced by the underlying rock. Harder rocks underlie the higher elevations since they tolerate the everyday weathering and erosional processes. Examples of these rocks in Adams County include quartzite, diabase, and conglomerate. Softer rocks like, shale, sandstone, and carbonate rocks (limestone and dolomite) underlie the valleys or lower elevations.

One doesn't have to look very far around the landscape to see a change in elevation. Geographers and geologists have divided regions up into what are called physiographic provinces. The characteristics that separate these provinces include type of terrain (valley, mountainous, hilly, etc.), rock types, vegetation and drainage. Adams County lies within two physiographic provinces as described below:

1. Ridge and Valley Province: Better known as the Appalachian Mountains, the terrain here is represented by alternating ridges and valleys. The South Mountain Section (SMS) lies along the northern and western edge of Adams County and is locally known as "South Mountain." Popular recreational areas within this section include Caledonia State Park and Michaux State Forest. Elevations range from 800-1,000 feet in the valleys and 1,400 - 2,100 feet on the ridges. Elevations of several higher landmarks: Rocky Knob - 1872; Graetenburg Hills - 1522; The Knob - 1894; Culp Ridge - 1416; Jacks Mountain - 1572.

2. Piedmont Province: Occupies the remaining portion of Adams County and is composed of rolling terrain with scattered valleys. The Piedmont can be subdivided into three sections within Adams County:

a. Gettysburg-Newark Lowland Section (GNLS): Occupies the area between South Mountain and the southeastern corner of the county. Elevation averages about 600 feet above sea level and in some areas, streams have cut downward into valleys 100-150 feet. Scattered hills ranging in elevation from 900 to 1,100 feet can be found, including foothills to South Mountain in the northwestern section of the county. Elevations of several higher landmarks: McKee Hill - 1186; Round Top - 785; Little Round Top - 650; Culps Hill - 600; and, Round Hill - 835.

b. Lowland Section (PLS): Elevations generally 400-600 feet above sea level characterized by a broad valley with isolated rolling and small rounded hills. Pigeon Hill, the westward extension of the Pigeon Hills of York County is 1021 feet above sea level.

c. Upland Section (PUS): Characterized by terrain averaging in elevation of about 700-800 feet, although the Pigeon Hills, located at the eastern border of the county increase in elevation of over 1,000 feet. This section is higher in elevation due to slightly more resistant rock compared to the PLS.

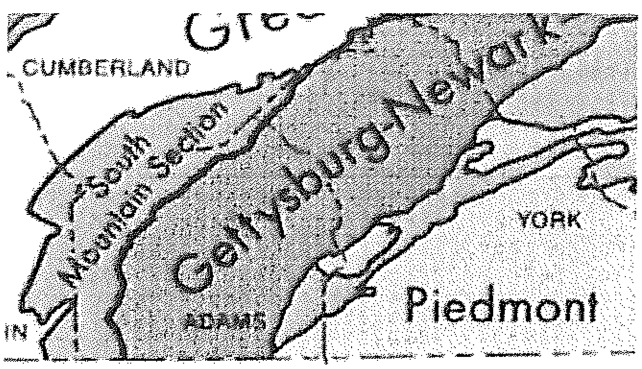


Fig. 2. Physiographic Province Map of Adams County
Adapted from Pa. Geologic Survey Map 13 (1999)

Adams County also spans two major drainage basins. The northern portion and most of the eastern part of the county ultimately drain to the Susquehanna River primarily by the Conewago Creek and its tributaries. The south-central and southwestern parts of the county, including the area around Gettysburg, are drained by tributaries (primarily Rock, Marsh, Middle and Toms Creeks) of the Monocacy River which empties into the Potomac River.

GENERAL GEOLOGY

Rocks found in Adams County range in age from at least 700 million years old to about 170 million years years. Rock types include sedimentary, igneous and metamorphic. The oldest rocks (Precambrian) are located within the SMS. The last rock-forming episode in the area occurred within the GNLS, the area that most of this trip today will be concentrated in.

Figure 3 is a stratigraphic column showing the formations found in Adams County. The youngest rocks are found at the top (diabase) while the oldest are at the bottom (Catoctin Formation).

Containing most of the oldest rocks in the county, the SMS has undergone several "mountain building" episodes. As a result, the rocks have been intensely folded and faulted. Geologists feel that the SMS has been folded into a arch shape with the arch leaning toward the northwest. Although not able to be seen by a passer-by, a major fault, the Carbaugh-Marsh Creek Fault, is located where U.S. Route 30 passes through South Mountain. From a satellite photograph, it is obvious that South Mountain north of U.S. Route 30 has been pushed about 4 miles to the west relative to the highlands to the south of U.S. Route 30 (Fig. 5).

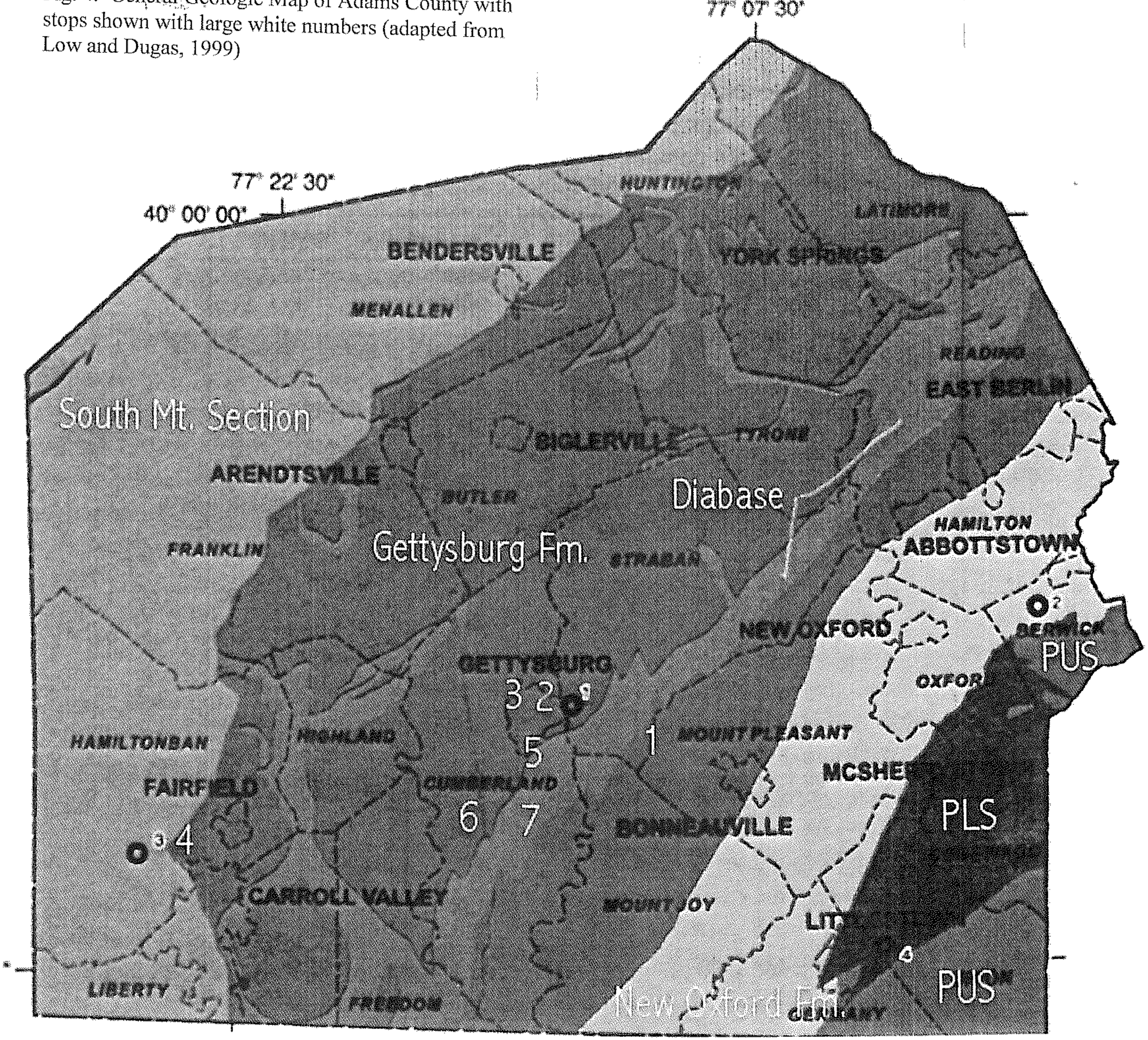
Figure 3. Geologic Formations in Adams County

Formation Name	Rock Type(s)	Thickness-Feet
Diabase	Dark-gray igneous rock	1800
Gettysburg	Shale, sandstone, conglomerate	16000
New Oxford	Sandstone, shale, conglomerate	6900
Beekmantown Group	Limestone, marble	300+
Conestoga	Limestone	1000+
Ledger	Dolomite, marble	2000
Kinzers	Limestone, marble	
Tomstown	Dolomite, limestone	1000+
Vintage	Limestone	500
Antietam	Sandstone, quartzite	800
Harpers	Siltstone, graywacke	2500-3100
Weverton	Quartzite, phyllite, graywacke	800-1000
Chickies	Quartzite, phyllite, conglomerate	800
Loudoun	Phyllite, graywacke	100-150
Catoctin metabasalt	Greenish volcanic rock	1000+
Catoctin metarhyolite	Reddish-to-purplish volcanic rock	2200-2900
Catoctin Schist	Greenstone Schist	100-150

Thickness from Stose (1932) and Taylor and Royer (1981)

The PLS and PUS have again been pushed and shoved due to at least one continental collision. Although continuous rock exposures do not exist to see examples of the folding and faulting, geologists carefully studying the strata can measure these structures.

Fig. 4. General Geologic Map of Adams County with stops shown with large white numbers (adapted from Low and Dugas, 1999)



The GNLS contains the youngest rocks in Adams County. These rocks were deposited after several episodes of "mountain building, thus the rocks have not been deformed. The rocks uniformly dip toward the northwest 20-30 degrees. Minor faulting occurs within this area. A major fault borders the western edge of the GNLS where it intersects with the SMS.

Various mineral resources have been removed from Adams County during historic times. These resources range from iron ore (magnetite, limonite and hematite), copper, ornamental stone, clay, sand, aggregate and lime.

Figure 5. Satellite photograph of South Mountain, PA
(taken from Way, 1986)

STOP 1. VALLEY QUARRY - GETTYSBURG

Location: Cumberland Township
Questions to be answered: Why do these rocks look like sedimentary rocks? What is a hornfels? Why all are of these minerals here? Why is the quarry so dry?

Known for many years as Teeter Quarry operated by the Harry Campbell Company, this operation is now owned and operated by Valley Quarries of Chambersburg, Pennsylvania. The quarry produces crushed stone or aggregate for use in road building and construction. This location has long been a favorite mineral collecting location for both amateurs (rockhounds) and professional collectors. In the early 1970's, many fine specimens of natrolite and stilbite were found here (Geyer and others, 1976). In the late 1980's, the operation exposed a large pocket of epidote, garnet and copper minerals, which attracted mineral collectors. The best published description of the minerals found here was conducted by Donald Hoff, curator of the State Museum of Pennsylvania (1978). Currently, Jeri Jones and Larry Eisenberger are working on a more complete updated article that will be published in the near future. Some of those findings are included within this report.

Before moving into the minerals, a quick glimpse around the quarry will show that most of the rock shows bedding. We are located within the Gettysburg Formation (GNLS). This rock belongs to the Triassic Period, dated approximately 200 million years ago. The same rock will be examined at Stop 3, however, the rock here has been changed by a nearby magma intrusion. Because of preference as to when to visit this quarry, we did this stop first rather than reversing the order. The rock was originally shale with a small amount of sandstone (sedimentary rocks), but with the introduction of the heat from the magma, the rock was "baked" (metamorphosed) and the mineralogical content of the rock changed to what is known as a hornfel (a metamorphic rock). The bedding is still present, but the rock has become denser and darker in color (due to a change in mineral content).

The rock that formed from the magma is known as diabase, a dark-gray coarse-grained igneous rock containing feldspar and pyroxene, along with minor minerals. When weathered, the diabase appears as a light-gray color taking on a rounded shape (spheroidal weathering). You will see classic examples of spheroidal weathering on the battlefield later in the day. The quarry has recently exposed the diabase in the northwestern corner of the quarry. Since the quarry is not equipped to handle crushing of the very hard diabase, the operation is now expanding to the north toward Pa. Route 97. The quarry is situated below (or beneath) the Gettysburg diabase sheet as both the hornfels and diabase are dipping gently toward the northwest (Stose, 1932) (refer to Fig. 6).

The operation today consists of three levels, each being about 50 feet deep. Recently exposed along the western wall in the bottom level are slickenlines (previously known as slickensides). This rock face is a large slickenlined feature that illustrates a fault here. You are looking at what geologists call a fault plane, the actual fault surface. As the two sides of the rocks moved against each other, not only were scratches grooved into the rock, but some polishing of the surface was also done.

Despite being below the level of nearby Rock Creek, this quarry is usually relatively dry. This is because the diabase and the hornfels, like many igneous and metamorphic rocks, have little or no primary porosity (ratio of the volume of voids or empty spaces in rock or soil to its total volume) and will not store very much water. Water only occurs in fractures or relict (leftover) bedding planes in the hornfels. Many of these opening have been filled with secondary minerals further reducing the space available for water. Diabase also has very low permeability (capacity to transmit fluid) and essentially acts as a barrier to ground-water flow (Taylor and Royer, 1981). We'll hear more about ground water at the next stop.

Larry Eisenberger has been collecting and studying the minerals from Valley Quarry for about 16 years. His research has yielded several new minerals not listed in print from this location. Although several of the minerals can be found in hand specimen, most of the minerals are found as "micros", meaning that a hand lens or microscope is needed to examine these species.

The following minerals have been identified from here: albite, andradite, bornite, calcite, chabazite, chalcocite, chalcopyrite, chalcotrichite, chlorite group sp. ?, chrysocolla, clay mineral sp. ?, cuprite, diopside, dioptase, djurleite, epidote, goethite, gypsum var. selenite, hematite, heulandite, idaite ?, laumontite, magnetite, malachite, mica sp. ?, montmorillinite, native copper, natrolite, opal, orthoclase, pyrite, pyrolusite, quartz, rutile ?, stilbite, stilpnomelane, titanite, tourmaline, and tremolite.

Most of these minerals are associated with the chemical reaction between the magma intrusion into the Gettysburg Formation rocks. Depending upon the temperature and composition of the magma at a certain point affected what mineral(s) would form. Some minerals will also change to adapt to a certain condition, often forming a new mineral (weathering). Hoff (1978) listed the following sequence of mineral formation (known to geologists as the paragenesis).

High Temperature - diopside, garnet, tremolite,
Medium Temperature - actinolite, epidote, quartz, titanite, apatite, chlorite, hematite, albte ?, orthoclase ?, magnetite, bornite ?, chalcopyrite ?
Low Temperature - stilbite, calcite
Weathering - goethite, chrysocolla, malachite

STOP 2. GETTYSBURG MUNICIPAL AUTHORITY WELL #6

Location: Gettysburg Borough
Questions to be answered: Where does Gettysburg get its drinking water? What is ground water? Why is there a large tower at the well site?

You are standing near Gettysburg Municipal Authority (GMA) Well #6, one of several sources used to supply drinking water to the Gettysburg community. The GMA community water system consists of a total of six permanent wells, one reserve well and a surface-water intake on Marsh Creek near the Sachs Covered Bridge. A little more than half of the drinking water is derived from ground water. GMA provides drinking water to the Borough of Gettysburg and portions of Cumberland and Straban Townships. The entire system is capable of producing about 2.5 million gallons per day (gpd) which may seem like more than enough to quench the thirsts of local residents and businesses. But if you factor in the number of tourists who visit Gettysburg, especially during the summer, the demand for water can be much greater on the system which has had to take some wells off-line due to hardness or other water quality problems. Adams County relies heavily on ground water as a source of drinking water. All but two of the 36 community water systems in Adams County rely solely on ground water and over half the population of the county is served by private, on-lot wells (DEP, 2001; EPA, 1996).

So, what is ground water and how does it occur? Water is continuously moving between the surface, subsurface and atmosphere. This recycling of water is known as the hydrologic or water cycle. As precipitation falls to Earth, most of the water is returned to the atmosphere by direct evaporation or transpiration from plants. Some of the water will runoff into surface water bodies and the remainder will infiltrate into the ground and eventually reach the zone of saturation where ground water occurs in the pore spaces and cracks (fractures) within rocks or sediments. With the rare exception of some limestone areas, ground water does **not** occur as an underground river. The top of the zone of saturation is called the water table and is generally a subdued reflection of the topography. Just like surface water, ground water flows along a gradient but generally at a much slower rate. Ground water will travel varying distances until it naturally discharges into streams, lakes, wetlands and springs. Ground water that discharges into stream channels is called baseflow which usually sustains over half the flow in a stream. During dry times, all of the water in a stream channel may be baseflow which emphasizes the intimate link between ground water and surface water (Fig. 7).

An aquifer is the name for geologic deposits capable of storing and yielding useable quantities of water. Aquifers are considered unconfined (also called a water-table aquifer) if the water table is free to rise and fall in response to precipitation and discharges or withdrawal. In unconfined aquifers, ground water flows in response to gravity. If a well is drilled into an unconfined aquifer, the water level will be the same as the water table. If an aquifer is overlain by an impermeable layer such as a clay layer or unfractured shale, it is considered to be confined (also called an artesian aquifer) because the ground water is under pressure (also called head). In wells drilled into confined aquifers, water will rise above the level where it was initially encountered. In some cases, the pressure may be great enough to allow the water to flow out of the well without having to pump it. This is known as a flowing artesian well.

Unlike surface water which must be filtered and treated for use by a public water system, ground water is generally of sufficient quality for drinking with no or minimal treatment. However, the activities of man can have a profound effect on ground-water quality. Leaking underground storage tanks, improperly operated septic systems, unsuitable disposal of industrial wastes and agricultural runoff are all examples of activities that can contaminate ground water. When planning a new public water supply well, a hydrogeologist must balance a number of factors such as hydrogeologic and engineering considerations, land-use in the area, known contamination problems and access for a drilling rig.

At this location, the likelihood of obtaining adequate water to meet demand was the basis for developing GMA Well #6 in 1986 despite the proximity of railroad tracks and gas stations (which are now gone). The well was drilled into the interbedded shales and sandstones of the Gettysburg Formation to a depth of 900 feet and penetrated 6 major water bearing zones. Figure 8 depicts the well log. A good yield was available as the well was determined to be capable of producing 329,000 gpd (228 gallons per minute). During the testing required to obtain a state operational permit for the well, contamination of the well by volatile organic compounds was discovered. The primary contaminants were chlorinated solvents similar to those used by a nearby business. Subsequent investigations determined that a leaking drain to the sewer and an old private well at the business allowed wastewater to contaminate both the shallow and deep parts of the aquifer. The area was further investigated and scheduled for remedial action under Pennsylvania's Hazardous Sites Cleanup Program. In 1987, GMA installed a packed column air stripping tower to treat the well for use as a public source of drinking water. GMA has incurred costs of nearly $400,000 to respond to the contamination of its well and the air stripper has annual operation and maintenance (O & M) costs of over $10,000. Abandonment of this high-yielding well and development of a new source was not really an option as it typically costs several hundred thousand dollars or more to explore for and develop a new municipal well which may not even have the same capacity as the abandoned one. Additionally, the Commonwealth of Pennsylvania has spent over $2 million in investigative costs and remediation (soil vapor extraction and air stripping at business site) with annual O & M costs of over $100,000 (EPA, 1996).

Obviously, it would be less expensive to prevent contamination of ground-water supplies than it is to treat them or develop new sources. Careful siting of new wells and ensuring that surrounding land use is compatible with a public water supply well will go a long way in protecting the water – and financial – resources of a community. The Pennsylvania Department of Environmental Protection (DEP) is currently promoting the concept of wellhead and source water protection to public water systems. These programs are designed to be community-based as only municipalities have authority to regulate land use. Local stakeholders are also in the best position to decide how to protect their drinking water. The Adams County Office of Planning and Development recently completed a DEP-funded study that included some pilot wellhead protection efforts for Abbottstown, Fairfield, Littlestown and Gettysburg.

STOP 3. SEMINARY RIDGE DIABASE/HORNFELS RAILROAD CUT

Location: Gettysburg Borough/Cumberland Township
Questions to be answered: Why do the sedimentary rocks change color? Which direction are the rocks dipping? Is the diabase more resistant to erosion? Which of these two rock types would be better at transmitting ground water?

The CSX Railroad cut is a good example of a dike. Here the igneous rock, diabase has intruded up through the reddish shale and mudstone of the Gettysburg Formation. Starting either from the west near the bridge or from the east behind Pizza Hut, the traditional reddish color of the Triassic-aged rocks can be seen. The rocks dip at about 25 degrees toward the northwest, similar to that seen at Valley Quarry at Stop 1. As one travels toward the contact with the diabase (hidden on the north side of the railroad by the man-made rock wall), one will notice that both the appearance of the shale and mudstones have changed. Notice that the color has changed from the reddish to a dark gray, hard, dense hornfels. If one could find the contact between the diabase and Gettysburg Formation, this would represent the highest grade (level) of metamorphism since the temperature was the highest here. The contact can be inferred on the south side of the railroad due to a discontinuous exposure. The direction and angle of dip has remained uniform through this exposure.

The diabase is known as an intrusive igneous rock, meaning that the rock solidified from magma deep within the Earth. Exactly how deep the magma was when cooling and crystallization occurred is undetermined. A rough figure of 1 mile beneath the surface is used by geologists describing the diabase intrusions. Just think, that means that about 200 million years ago, the Earth's surface at this locality was about 1 mile above our heads. So what happened to all of that material? It is called weathering and erosion, the primary geologic force that is affecting rocks on the East Coast today. If you examine the diabase here, several hints of its origin can be told by looking at some features. First, examine the size of the groundmass. Are the mineral grains large enough to identify or are they too small to see without the aid of a microscope? Here, the rock is termed fine-grained. This means that the rock crystallized quickly (a relative term with no exact years attached).

So what is a dike? A dike is defined as "A tabular body of igneous rock that cuts across adjacent rocks........" (Parker,1997). Standing at the intersection with the diabase and Gettysburg Formation rocks, picture this dike measuring only 92 feet (Stose and Bascom, 1929) Fig. 9, 10). Compare this thickness of 92 feet with the diabase sheet seen at Stop #1 which was 1,800 feet thick (Stose,1932). Although the dike is less than 100 feet wide, the dike runs nearly the entire width of Adams County, north to south. The dike originates at the south out of the diabase sill near Greenmount and extends northward to near Goldenville where it splits into two. Further to the north, the dike run into larger diabase sheets (Taylor and Royer, 1981)

Fig. 10. Photograph of the diabase dike taken circa 1980 (taken from Shirk 1980)

This site is not that far away from the last stop where we talked about ground water. GMA Well #6 was drilled into shale that is similar to the "unbaked" shales here. The diabase here is typical – very dense and very low primary porosity, so ground water would only occur in the fractures. The shales do have some porosity but the fracturing and bedding allow more ground water to occur. Diabase is one of the poorest aquifers in Pennsylvania although adequate domestic yields of a few gallons per minute are possible. Compare that yield to that of GMA Well #6.

This is a good opportunity to investigate some geologic history. As geologists are sometimes viewed as private detectives gathering clues and then making some sort of hypothesis, using evidence seen in both the sedimentary rocks and diabase, we are able to draw some conclusion as stated below:

1. Calcite (white) is found as scattered grains throughout the shales. The calcite is pseudomorphed after glauberite. Isolated glauberite crystals are sometimes found in sedimentary rocks formed in arid environments.

2. The reddish color of Triassic rocks is caused from iron oxide formed as a result of the deep weathering of pre-existing rocks from which these clay-sized grains were derived. If the GNLS was a lowlands area during the Triassic, the sediment was washed in from the highlands to the south and east (for example the PLS and PUS). The iron oxide also shows that this sediment formed in an Everglades-type environment.

3. Because the diabase cuts through the Gettysburg Formation rocks, the diabase is considered younger in age, a principle known to geologists as cross-cutting, one aspect of relative time. In fact, through dating of the diabase throughout southeastern Pennsylvania, the diabase is now considered Jurassic in age (190-170 million years old).

Red soils on silicate rocks are presently forming under atmospheric conditions which reach a minimum average yearly temperature of about 60 degrees F. and a minimum yearly rainfall of about 40 inches. Paleomagnetic studies place the Gettysburg area around a latitude of 10 degrees N. during the Triassic Period. Other data supports that the climate of the Triassic was hot and humid (tropical) with an annual temperature averaging over 75 degrees F. and rainfall in excess of 50 inches (Shirk, 1980).

POST SCRIPT: Although this outcrop is still a decent example of a dike and associated contact metamorphism of the surrounding country rock, the outcrop was a classic example prior to 1991. Then, almost the entire width of the dike and its contact with the shale was exposed in the cut as depicted in Shirk (1980) (Fig. 10). In September 1990, Congressional legislation that expanded the Gettysburg National Military Park by nearly 2,000 acres included provisions for a controversial land trade between the National Park Service (NPS) and Gettysburg College. The exchange resulted in the college receiving 7.5 acres of adjacent park land along the ridge and NPS obtaining development rights to 47 acres of college athletic fields that were on or near the battlefield. College officials sought the trade to allow relocation of railroad tracks that traversed the campus and the NPS wanted to ensure the 47 acres would not be further developed. Despite objections from historians and preservationists that the section of the ridge transferred to the college was the scene of significant action on the first day of the Battle of Gettysburg, the NPS maintained that the trade would "not have adverse impact on known historic resources". It was never revealed at public meetings or to the Pennsylvania Historical and Museum Commission, which also had oversight, that any excavation would occur. In a surprise move in January 1991, Gettysburg College began excavating over three acres of the railroad cut (about half the land it received) in order to move the railroad tracks as far as possible from campus and to add a new rail spur. The excavation significantly altered the appearance of this part of the ridge and essentially destroyed the once-classic outcrop. Subsequent erosion of the cut, particularly in the area of the diabase, led to the placement of a gabion wall to limit erosion. The wall now covers the dike and its contact with the shale. A 1991 lawsuit brought against the college and NPS by the Gettysburg Battlefield Preservation Association and a 1994 Congressional investigation were not successful in having the ridge restored but did point out shortcomings in the case and underscored the importance of full public review in dealing with public lands (Fitts, 1994; Sipkoff, 1994). Historians may still push for restoration of the ridge, but geologists have lost a textbook teaching example. Since any historical significance of the railroad cut was seemingly ignored, it doesn't seem likely that the geological significance would have been much of a factor either.

STOP 4. VALLEY QUARRY - FAIRFIELD

Location: Hamiltonban Township
Questions to be answered: Why does this rock look so different? Why is there so much water in the quarry? What are the thin light brown rock layers? Was this rock affected by a diabase intrusion?

Valley Quarries, Fairfield quarry, mines a limestone conglomerate for the production of crushed stone. In an effort to expand these limestone resources, in the fall of 1992, a series of coreholes was drilled in the property on the west side of Bull Frog Road. The drill cores included many unbroken multi-foot sections that included a "profitable" reserve of limestone Based on cross sections drawn from the cores, the rock unit is projected to be at least 300 feet thick (Britcher, 1993). In the spring of 2001, stripping of the overburden began to uncover the limestone.

The limestone conglomerate is not an uncommon rock, but its occurrence here appears to be an unique opportunity to look through the Triassic rocks (Fig. 11). Stose and Bascom (1929) did recognize this rock in detailed survey of the area. Stose and Bascom also recognized a similar limestone conglomerate bordering the Triassic area on the west, but the Fairfield area rock was somewhat different for some unknown reason. They placed the age of this limestone as probable Triassic, since it was located with the GNLS. Recent thinking by some stratigraphers now believe that this rock is *NOT* Triassic in age, but possibly Lower Paleozoic age, but uncertain affinity with a particular formation (Britcher, 1993). If this is true, Triassic rocks (Gettysburg Formation) have been removed by weathering and erosion, giving geologists this "window" to view the older underlying rock. On a regional scale, if we could remove all of the Triassic rocks, we would indeed see older (Lower Paleozoic) rocks underlying the area.

What is a limestone conglomerate? First, a conglomerate is a rock that contains rounded pebbles cemented into a finer-grained groundmass (Fig. 12). A conglomerate is considered a clastic sedimentary rock, meaning that the rock is composed of "pre-existing" rock fragments. Since we use the word limestone with the rock, that means that the rock is composed of at least 50% calcium carbonate (calcite). The rock will fizz with the introduction of hydrochloric acid. The pebbles (or clasts) in this rock are subangular to rounded and range in size from 0.5 inch to 11 inches. Composition of the clasts are limestone. The rock is termed poorly sorted since a wide range of clast size can be found in one rock. To a person that studies the formation of sedimentary rocks (sedimentologist), these two attributes could lead to a possible water origin of the rock as follows:

> Poorly Sorted: Water did not sort particles well, but was strong enough to carry up at least 11 inch fragments.
>
> Subangular to rounded: Since these clasts are fragments from previous bedrock, these fragments were carried by water from a moderate distance (relatively speaking).

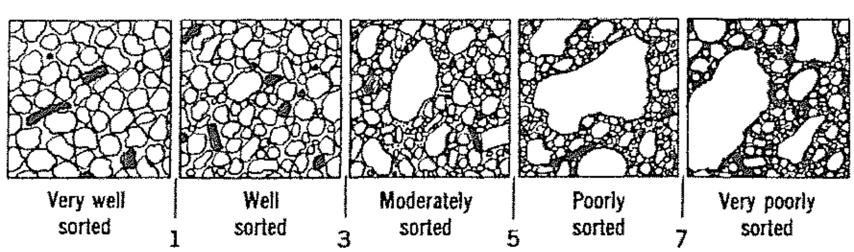


Fig. 12. Classification of sorting (from Compton, 1962)

Within the quarry, one will see that there are light-colored interbedded mudstones within the limestone conglomerate. All of the strata dips toward the north at 23-25 degrees. Nearly vertical joints (fractures that have no measurable movement like a fault) are found on all four levels of the quarry. These are particularly noticeable on the second level on the north wall. A zone of highly fractured limestone conglomerate is also found in this same area. Springs are particularly common on level four along the south and west walls. The rocks here are not as "tight" as rocks like the diabase and allow for more storage and movement of ground water as evidenced by the fractures and springs.

With the texture of the rock, there has been some consideration of using the limestone conglomerate as a dimension rock. Samples were tested for a potential as marble tile. The tests took into account color, range of clast size and shape, uniformity of texture, hardness, and resistance to abrasion (Britcher, 1993). Test results were encouraging. To date, Valley Quarries has not moved any further on pursuing this product.

The Gettysburg diabase sheet is found on the ridge immediately to our east. This is the same intrusion that we saw at Valley Quarry - Gettysburg. The only difference is that here we are located above the sheet verses at the bottom at Stop #1. Although this rock is not considered to be Triassic, the diabase has still affected the rock in a similar fashion as at Stop #1. The heat and fluids from the intrusion left deposits of diopside, andradite garnet and flecks of pyrite. Pyrite weathering to goethite can be seen within the mudstone unit. There are noticeable reaction rims around the clasts (Britcher, 1993). Lapham and Geyer (1969) reported apophyllite, calcite, chacopyrite and garnet (probably andradite) from this locality. Larry Eisenberger has observed the following minerals: laumontite, heulandite, stilbite, chabazite, garnet sp. ?, wollastonite, vesuvianite, pyrrhotite,wurtzite, chlorite, diopside, tremolite, quartz, opal, marcasite ?, goethite, galena and gypsum variety selenite.

In comparison to Valley Quarry - Gettysburg, some of the mineral species are similar, but noticeably different is the lack of epidote, feldspar and copper at the Fairfield plant, possibly due to the location of the quarries relative to the diabase sheet (above or below).

STOP 5. CONFEDERATE AVE./EISENHOWER FARM OBSERVATION TOWER PARKING AREA

Location: Gettysburg National Military Park
Questions to be Answered: What are those mountains in the distance? What is a physiographic province? What happened during the Triassic Park in this area? What happened at this location during the Battle of Gettysburg?

Our geologic emphasis here is two parted: 1) Show the difference between two physiographic provinces, and 2) visualize what happened here during the Triassic Period. This is also our first stop that will also involve the story of the most famous conflict during the Civil War, the Battle of Gettysburg. Time has been planned into the schedule for anyone to ascend the observation tower for a better view.

As stated in the Introduction, the area of our tour today lies totally within the Piedmont physiographic province. Basically, when we talk about physiography or geology, the information can be extended across geographic or political borders. The Piedmont extends from southern New York southward into Alabama. Piedmont is defined as "The tract of country at the foot of a mountain range." The word is derived from the Italian piemonte, meaning "mountain foot." (Allaby and Allaby, 1999). Another physiographic province is visible in the distance (Fig. 13). This is known as the South Mountain Section (SMS) of the Ridge and Valley province. The quick change in elevation, type of terrain, and type of vegetation are characteristics of a change of province. Rock types within the SMS are much older (700-550 million years old) and are complexly folded (bent) and faulted (broken) (Way, 1986; Fauth, 1968; Sevon and Potter, 1991). In fact, the oldest rocks within this section are volcanic in origin, in which the copper deposits in southern Adams County are associated (Stose and Bascom, 1929). The SMS is a new revision made by the Pennsylvania Geologic Survey. Previously, the SMS was regarded a portion of the Blue Ridge province (better known as the Blue Ridge Mountains in Maryland, Virginia, North Carolina and Tennessee). A closer examination of the geology appears to closer match that of the Ridge and Valley province, rather than that seen within the Blue Ridge Province.

As you look over the rolling hills of the GNLS, try to imagine what this area was like 220 - 170 million years ago during the Triassic and Jurassic periods. As a result of the formation of Pangaea some 340 million years ago, the Appalachian Mountains (Ridge and Valley province), GNLS and the PLS and PUS were pushed up and were considered "highlands." It was during the Triassic/Jurassic times that Pangaea began to break up in to the world we know of it today. Stationary columns of magma coming up from the lower crust and upper mantle of the Earth's interior, known as hotspots, are believed to be the driving force for this breakup. Hotspots along with convection currents within the upper mantle of the Earth rifted Pangaea apart. The sequence of events is outlined below for the GNLS millions of years ago (MYA):

230-220 MYA Erosion and weathering from heavy rainfall washes sediment from the south and east into the rift valley, eventually forming the New Oxford Formation, which is about 6,900 feet thick (Taylor and Royer, 1981).

220-190 MYA Rift valley continues to be pulled apart. Acting in a hinge-like effect on the east side of the rift valley, the basin slowly tilts downward toward the northwest. A major "border" fault either forms or possibly an old fault became reactivated along the western edge.

220-190 MYA Weathering and erosion of rocks from the north and west (Ridge and Valley Province) caused sedimentation to wash into the rift valley overlying the New Oxford Formation. This additional weight continued to tilt the crust toward the northwest up to forty degrees. This sedimentation eventually formed the rocks of the Gettysburg Formation.

190-170 MYA Due to fracturing and rifting taking place, magma originating from the lower crust and mantle intruded up through bedrock including the New Oxford and Gettysburg Formation rocks. These intrusions formed dikes, sills and some lava flows. The magma cooled and formed diabase. Although most of the diabase is confined to the GNLS, there are dikes found in the PLS, PUS and the Ridge and Valley Province. Smith and others (1975) show that three different magmas originated from various depths based on chemical composition. They refer to these diabases form oldest to youngest: Quarryville type, York Haven type (as seen at Stop 1) and the Rossvile type (as seen at Stop 3).

180-160 MYA Rift valley failed. Africa and North America pulled apart off of the East Coast. **If the GNLS rift would have been successful, we today, would be a part of northwestern Africa!**

Dates for the Triassic formations and diabase intrusions are from Berg and others (1993).

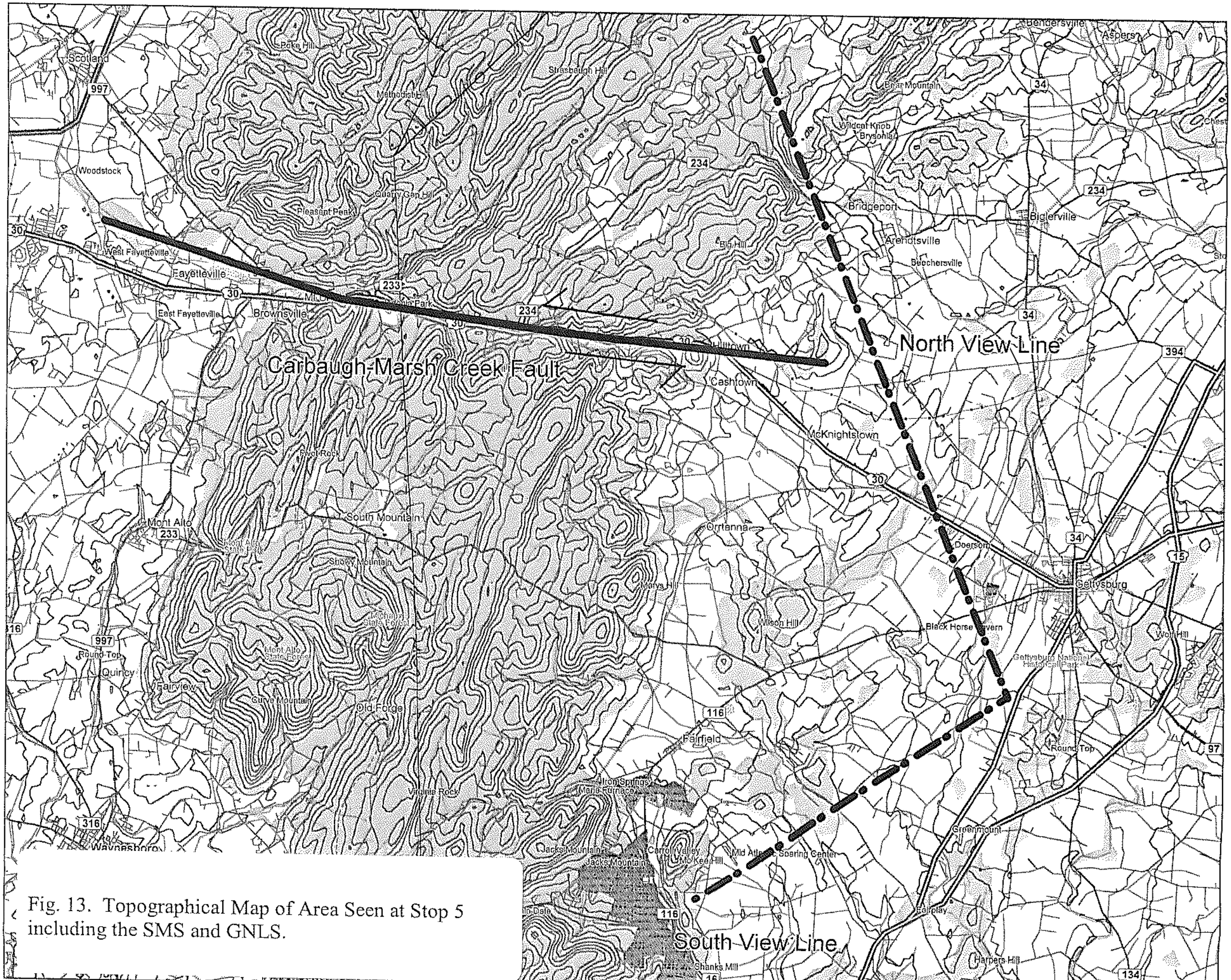


Fig. 13. Topographical Map of Area Seen at Stop 5 including the SMS and GNLS.

1 mi Scale: 1 : 150,000 Detail: 10-4 Datum: WGS84

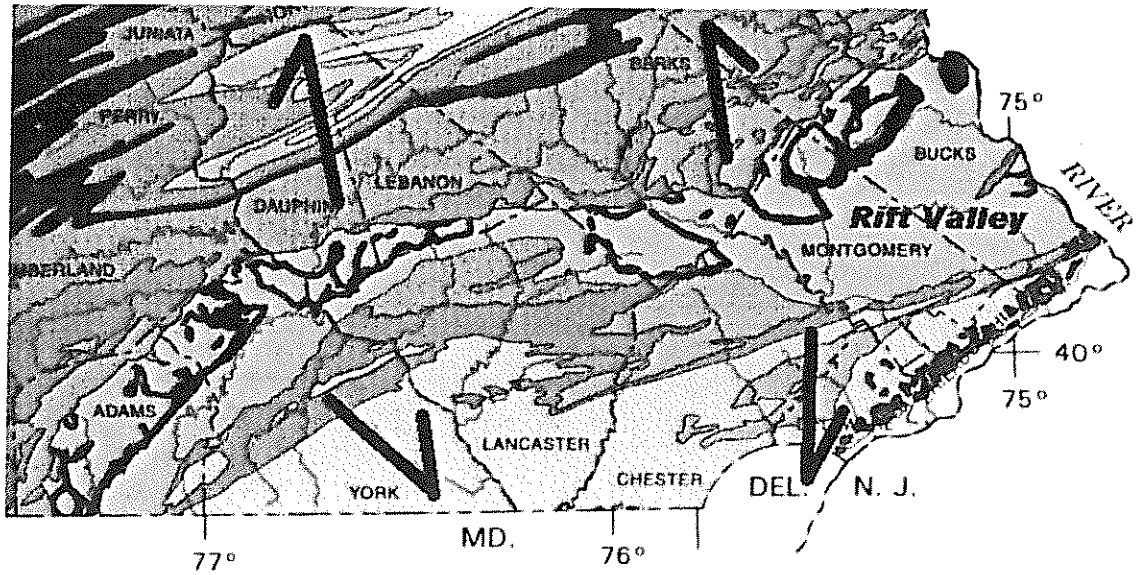


Fig. 14. Rift Valley during Triassic/Jurassic times.
Black areas within rift valley are diabase intrusions.
Adapted from Pa. Geologic Survey Map # 7 (1990)

STOP 6. BRIDGE OVER PLUM RUN

Location: Gettysburg National Military Park
Questions to be Answered: Why do some of these rocks look strange? Are there really foot tracks in these rocks? Did we really have one of the oldest dinosaurs living right here?

Many of us take bridges for granted. They are right where we need them to cross either natural features or man-made structures. How many of us, though, stopped to look at rocks that stone bridges are made from? Take this bridge for example, how many cars travel past this point in a year's time and never bother to stop? If someone would stop here and really give these rocks a "looking over", they would find some interesting markings. Coming to the bridge over Plum Creek is like going to an earth science laboratory exercise with a geologist. All of the rock used in this bridge was quarried out of Adams County. Diabase is scattered among the rocks and some of those pieces still show impressions where facing tools chiseled the rock. Most of the rock, other than the diabase, was quarried from Trostle's Quarry, an operation that became famous in July 27, 1937, when approximately 50 foot tracks of dinosaur and reptilian creatures were discovered (Cleaves, 1937). In total, four different species of Triassic vertebrates were identified from here (Baird, 1993). Although the rock has been altered similar to those observed at Stop #1, the fossils within the rocks remained well preserved. These rocks belong to the Gettysburg Formation, giving these fossils an age of approximately 209 million years old.

The tracks seen here belong to the dinosaur Atreipus milfordensis. The genus name honors Atreus Wanner, one time principal of York High School who first published on tracks of this type in 1889. Atreipus has a three-toed hindfoot and was quadrupedal, with small hoof-like front feet leaving (usually) 3-toed imprints. The hind feet are always larger than the front feet (Fig. 15). These footprints are similar to several other plant-eaters, so the Atreipus footprints provide one of the earliest records of herbivorous dinosaurs (Ornithischia) in North America (Baird, 1993). Total length was six to eight feet (Fig 15)

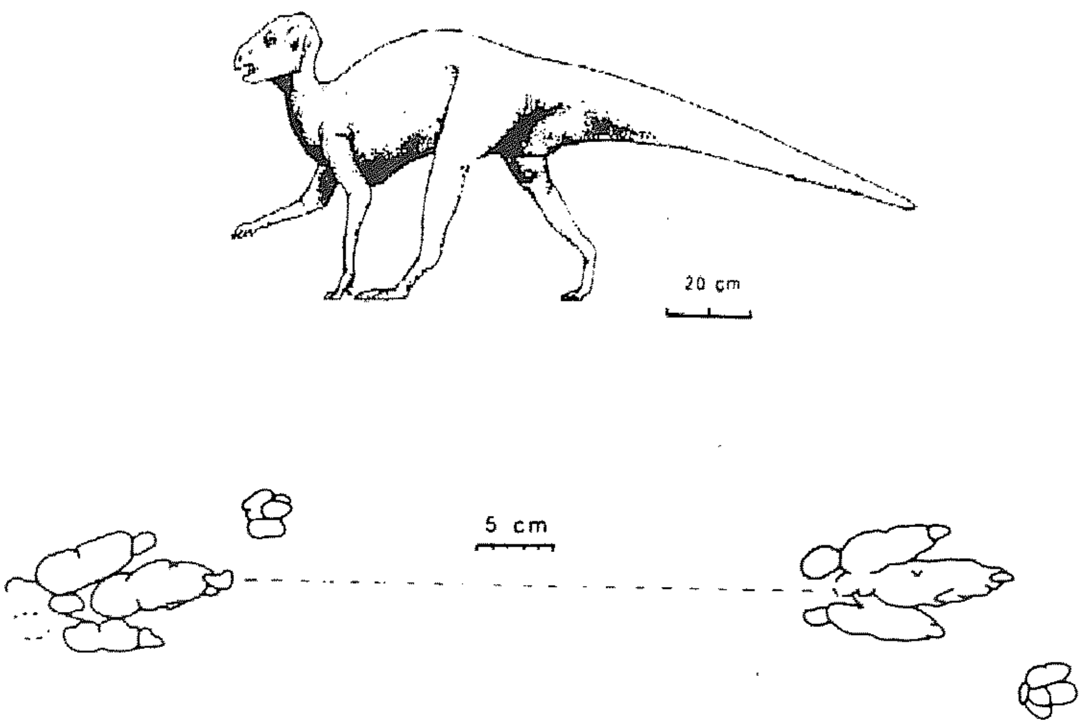


Fig. 15. Top - Hypothetical reconstruction of Atreipus milfordensis.
Bottom - Outline pattern of Atreipus milfordensis foot prints. Larger tracks are from the back feet while the smaller tracks are from the front.
Both illustrations from Olsen and Baird, 1986).

Other features observed in the rock are all sedimentary in origin, in other words, formed when the sediment was being deposited. These markings, like ripple marks, scour marks, load casts, and raindrop imprints are very common. Several surface markings on some slabs were initially thought to represent impressions of dinosaur skin are now interpreted as one of the above sedimentary features. These markings greatly assist the geologist in interpreting the environment in this area during Triassic times (Fig. 16). The same processes that affect our Earth today have been at work for millions of years. This principle is known as uniformitarianism. For example, since we understand and observe how ripple marks are formed by the ocean water along the beach today, a rock that has ripple marks can be correlated with that environment.

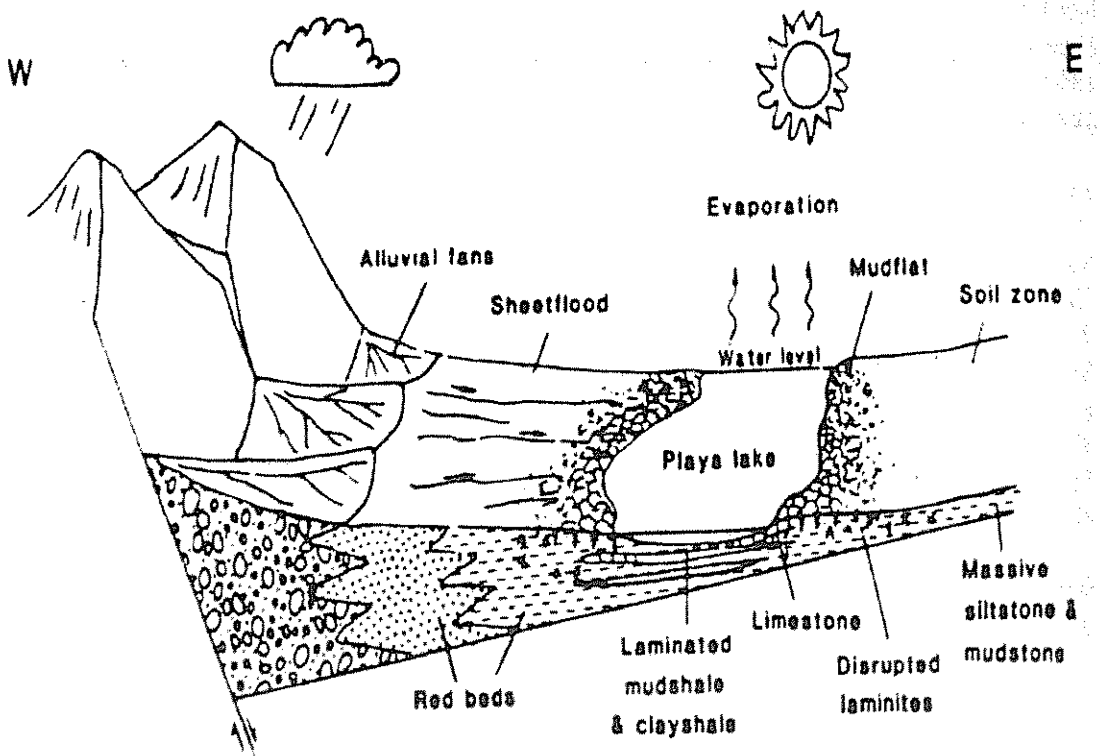


Fig. 16. Cross section and paleoenvironmental model of a Mesozoic rift basin. (From Gore, 1988).

STOP 7 - LITTLE ROUND TOP

Location: Gettysburg National Military Park
Questions to be Answered: Why the change in elevation? How can geology affect a battle? How did this location play a role in the battle? Why are there "paleo bowling balls" lying everywhere?

From this point to the west about one mile, you can see Seminary Ridge (Fig. 17). The ridge is formed by a diabase dike. Two key strategic areas in the battle are found in the valley between these two diabase ridges: the Wheatfield and Peach Orchard. Intense battling went on here for six hours in a back-and-forth conflict in the second day of battle on July 2, 1863. Little Round Top marks the southern end of the "fish hook" defense line of the Union Army, and from this vantage point, over half of the Union line could be seen (Fig. 17).

By the afternoon of July 2, neither army occupied this position, but Union signal flag men used this spot as a communication point. By late afternoon, Little Round Top started to become the focal point of control as Confederate sharp-shooters have positioned themselves among the large diabase boulders of Devil's Den. Two cannons were brought to the crest of Little Round Top and their aid tipped the fateful hand of the battle for this position in favor of the Union troops. On July 3, the Confederate sharp-shooters attempted to shake the Union off of this point. Because the soldiers could not dig in on Little Round Top, the Union army took a severe hit with many fatalities, but held control of the hill.

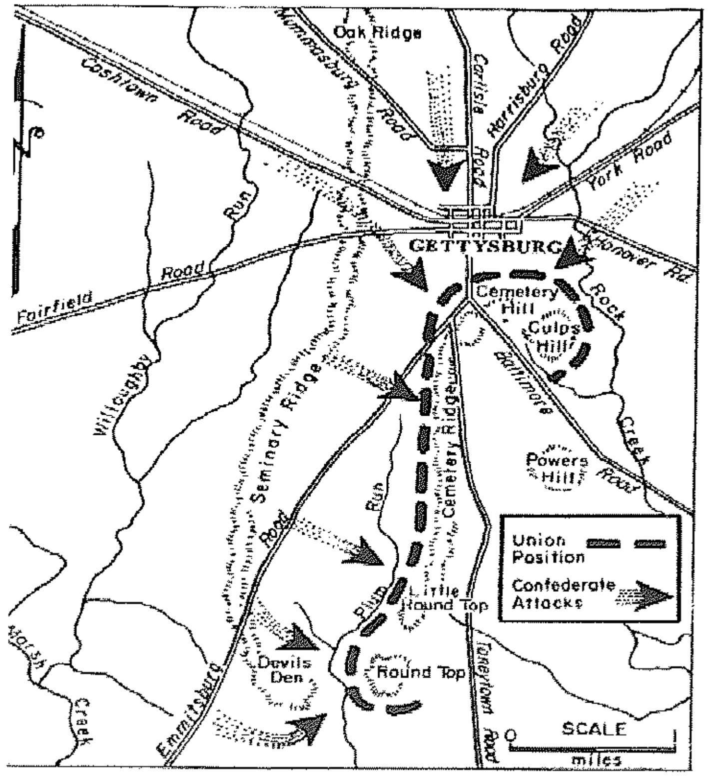


Fig. 18. The Gettysburg Battlefield (from Brown, 1997)

Geology did play a large part in the Battle of Gettysburg! Both General Lee (Confederates) and Meade (Union) had a background in geology and geography. In fact, prior to the start of the Battle of Gettysburg, both armies sent surveyors to Gettysburg to prepare a topography map of the area. These maps were then utilized in planning the strategy of how to win the conflict. As a result of the surveys, both sides had concluded to themselves that who ever would win control of Little Round Top would probably win Gettysburg. Little did anyone know that this was true, but also the winner of Gettysburg would also be victorious in the Civil War.

A big factor with this war centers around a rock that you have heard much of today. It is called diabase, those big, "hard-looking" massive boulders that are scattered around the battlefield and, as we know, are common in Adams County. Diabase turns out to be the primary "hiding" place for the soldiers. Areas underlain with diabase does not allow for any trenching, the primary method of defense. Soil profiles in these areas are quite shallow before hitting bedrock. The overlying clay is also has a sandy clay composition, making it hard to penetrate. Trenching was out, so in areas like the Peach Orchard and Wheatfield, hand-to-hand combat was common. Those who could take control of areas like Devil's Den, Little Round Top and Seminary Ridge had an advantage.

The diabase at Little Round Top and Devil's Den displays classic examples of exfoliation and spheroidal weathering. Exfoliation is a mechanical weathering process where concentric shells or plates are spalled or stripped off from a large rock mass. Curvilinear joints form from differential stresses caused by expansion of once deeply buried rock as overburden pressure is reduced by erosion. Water then enters these joints and frost heaving (a daily cycle of freeze-thaw during cold weather) further promotes the exfoliation process. The result is a rounded rock mass. Although related to the exfoliation process, the smooth, rounded to sub-rounded diabase boulders are thought to have formed primarily by spheroidal weathering which results from the mechanical effects of chemical weathering in which concentric shells of decomposed rock are loosened and separated from a rock block in similar fashion to an onion skin. As feldspars weather to clay minerals, there is an increase in volume of the rock which creates internal pressure on the rock that ultimately breaks down the rock mass at its greatest exposure to the elements such as corners (more surface area exposed), joints and fractures (Shirk, 1980; Bates and Jackson, 1987). Weathering related to organic activity such as tree and root wedging and lichen encrustations are also observed in the diabase.

Time has been built in for anyone wishing to hear the fascinating story about how the low-numbered Maine Brigade held off a large Confederate charge on the east side of Little Round Top may walk the paved 0.25 mile trail to the monument. It was actually this encounter that ended the Battle of Gettysburg.

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