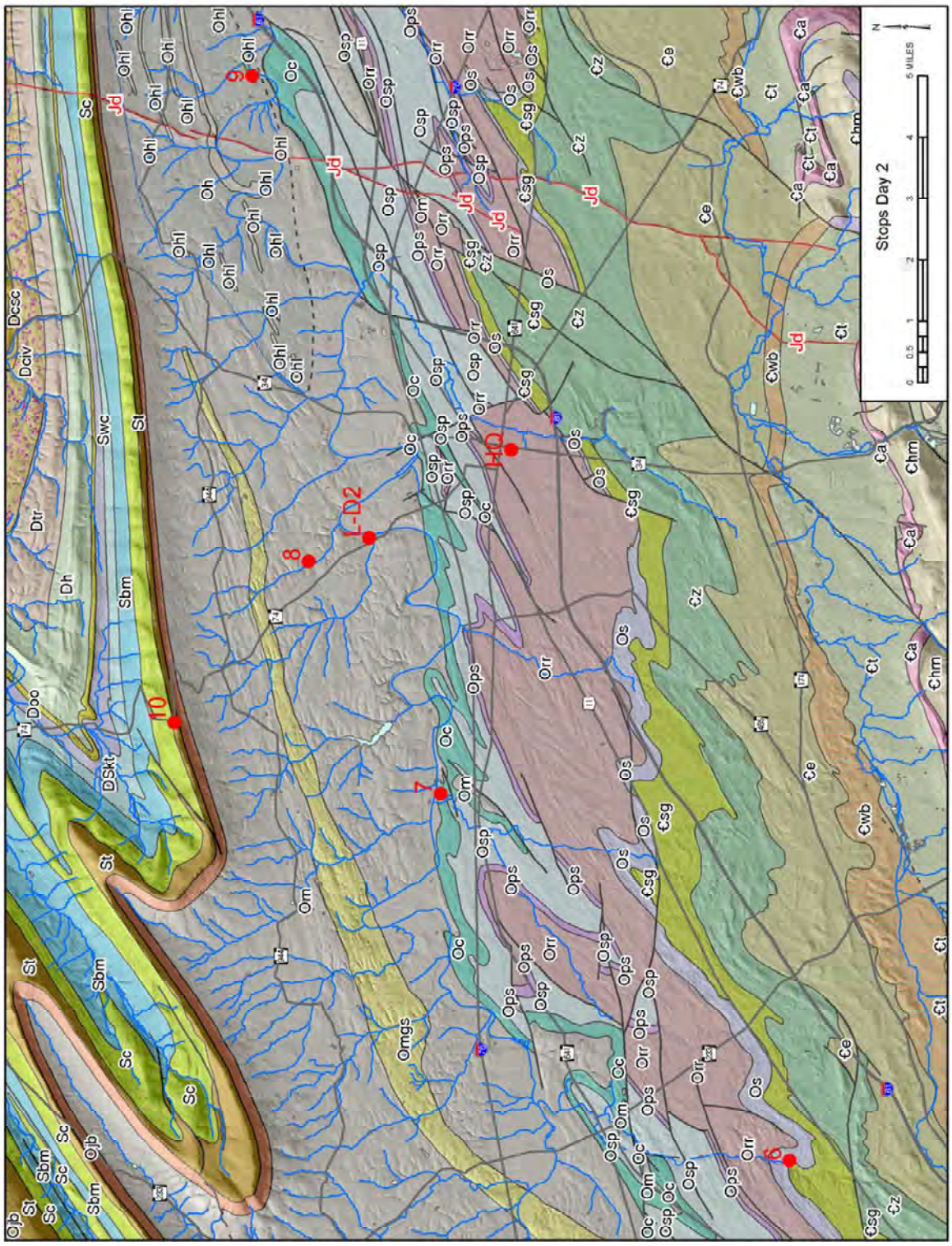
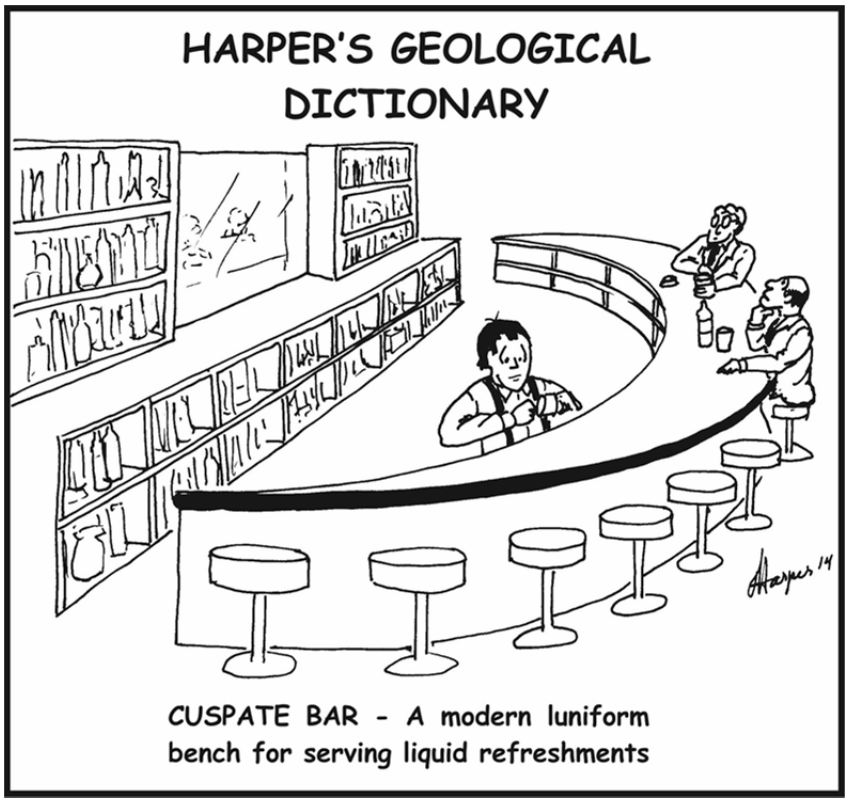


Day 2 Road Log. LiDAR image with Geologic Map showing Stops 6 – 10, Starting at Comfort Suites in Carlisle (HQ) & including Lunch Stop (L-D2)


HARPER'S GEOLOGICAL DICTIONARY
CUSPATE BAR - A modern luniform bench for serving liquid refreshments

Interval Mileage	Cumulative Mileage	**STOP = Stop Sign; = Traffic Light; "T" = T Intersection; TR = Township Route; "Y" = Y intersection**
0.0	0.0	Start at Carlisle Comfort Suites. Drive south on South Hanover Street passing several traffic lights toward I-81
0.7	0.7	***Turn slight right*** to merge onto I-81 S
9.7	10.4	Take Exit 37 onto Pa Route 233 toward Newville; ***turn right*** at
1.1	11.5	***Turn left*** at onto US Route 11 (Ritner Road)
3.9	15.4	***Turn right*** onto Oakville Road (TR 386)
0.8	16.2	***Turn right*** onto Springfield Road (TR 333)
1.2	17.4	***Turn right*** on Horn Road (opposite to Willis Road)
0.2	17.6	View to right of pinnacle weathering of carbonates and sinkhole
		View of sinkhole and associated 'pinnacle' weathering along Horn Road in the Shadygrove Formation. *Pinnacle weathering is prevalent in the Great Valley Province, but is rarely seen*
0.4	18.0	***Turn left*** onto Big Spring Road (SR 3007). Unoccupied buildings along the route for the next 0.3 miles are of a former PA Fish Commission Hatchery whose operation closed due to pollution of Big Spring.
0.4	**18.5**	***ARRIVE*** **at parking area for off-loading to view Big Spring Run, the USGS gaging station & local geology – STOP 6**

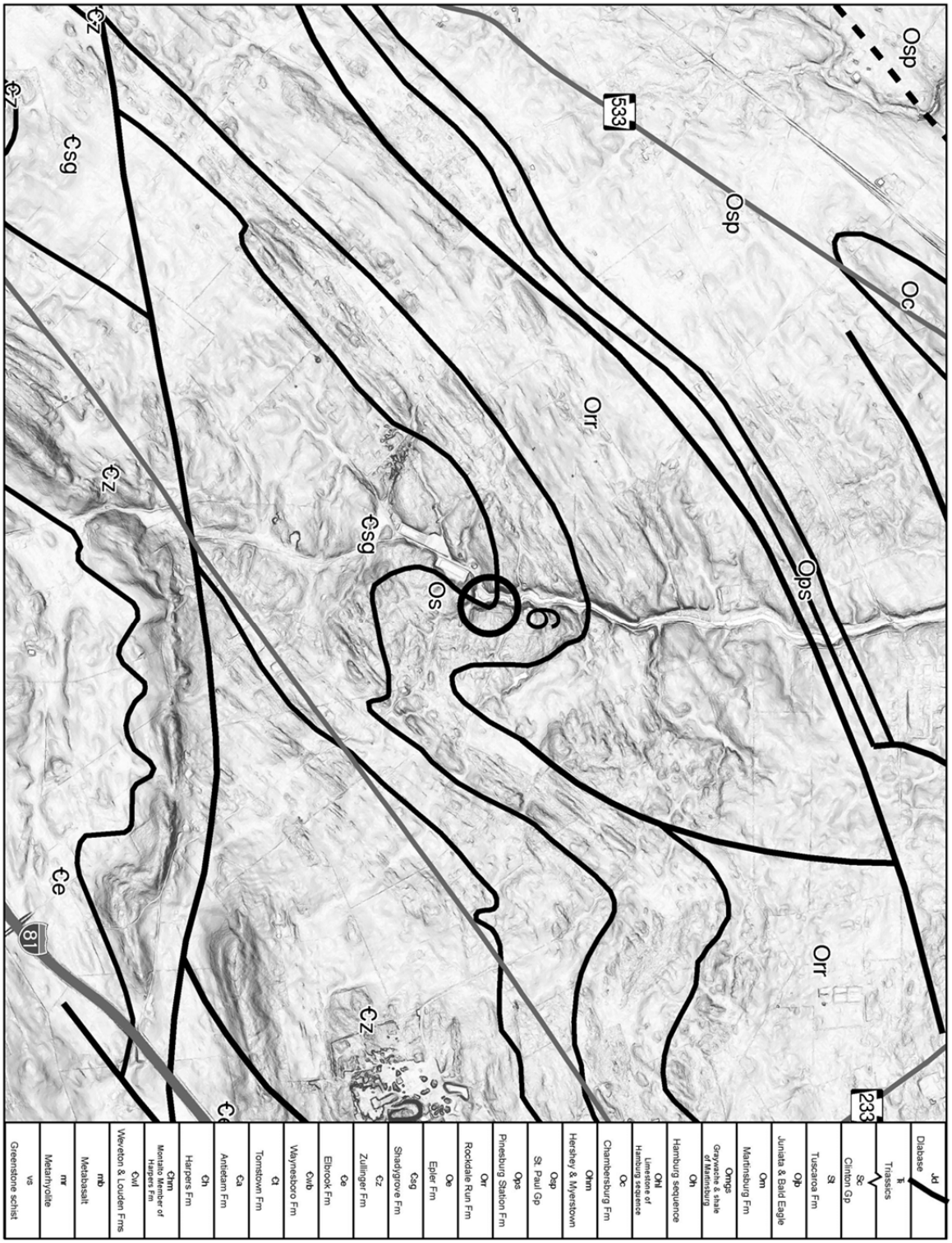


Figure 1. LiDAR image of Stop 6 – Big Spring area, with geologic contacts overlain.

STOP # 6 – BIG SPRING

Stop Leaders
Todd Hurd, Shippensburg University;
Noel Potter, Dickinson College, Retired

USGS Gaging Station at former dam below Big Spring

Big Spring (40°7'42.6"N, 77°24'26.6"W) is considered one of the largest springs in Pennsylvania (Figure 1 – LiDAR). Big Spring actually consists of two springs spaced ~50 m from one another. The "West" spring is the main source of water, which joins with a smaller flow from the "East" spring to feed Big Spring Creek that flows northward in a broad, shallow, valley that appears to be a collapsed cave passage. In places, weathered travertine deposits are visible on rock outcrops near the main fish hatchery buildings, and cave passages and springs are known to lead laterally from this valley.

Big Spring occurs at or near the crest of an eastward plunging anticlinal fold in the Ordovician Stoufferstown Formation (Becher and Root, 1981). Outcrops can be examined on the west side of the road opposite the creek. There beds average about N60°E, 20°-77°NW indicating that they are on the NW flank of the anticline. Outcrops south of the springs on the east side of the road have gentler eastward dips indicating they are near the anticlinal fold hinge. Use caution in distinguishing often more prominent SE-dipping cleavage from bedding.

Prior to the 2005 dye trace the recharge area for Big Spring was thought to extend directly upgradient toward South Mountain. In a 1981 PGS report Becher and Root discuss the lack of needed size for a watershed toward South Mountain because of the location of Yellow Breeches Creek (Becher and Root, 1981). With limited discharge measurements and existing water table maps they concluded that flow was lost from the Yellow Breeches to sustain flow at Big Spring. The 2005 dye trace (and subsequent traces) have documented the importance of bedrock structure on creating an anisotropic groundwater flow along the NE trending strike in the valley, nearly perpendiclular to the regional hydraulic gradient.

Big Spring Flow

Flow from Big Spring sustained a large State fish hatchery for decades before water quality issues dictated its closure. Although much of the infrastructure has been

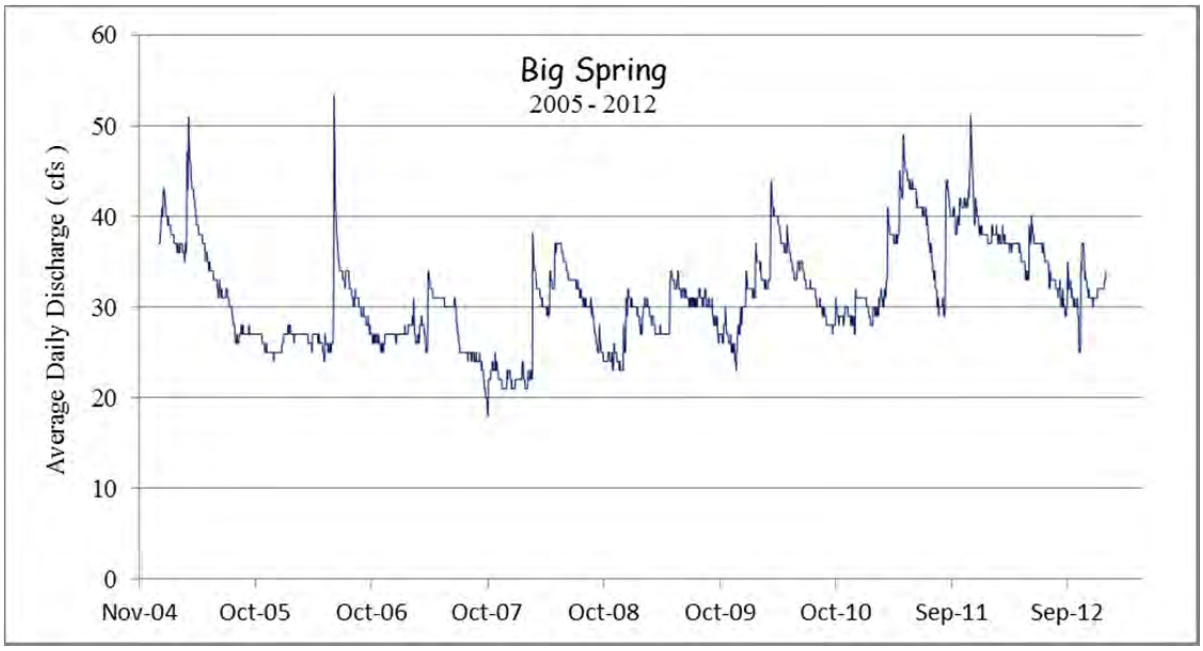


Figure 2. Average daily discharge mesured 100m downstream of Big Spring on Big Spring Creek over an eight year period. All data from USGS.

removed, the pump house remains next to the main West Spring. In November 2004 the USGS began data collection at Big Spring as the direct result of a permit condition tied to the creation and operation of a limestone quarry located 2.5 km due east. The USGS measures discharge, temperature, and turbidity at a gage located approximately 100m downstream of the main spring head at the breastworks of an old mill below what is locally called “The Ditch.” Average daily discharge collected over an eight year period shows a remarkably consistent flow, varying from a low of 18 cfs to a high of 52 cfs (Figure 2). The average daily flow is approximately 31 cfs.

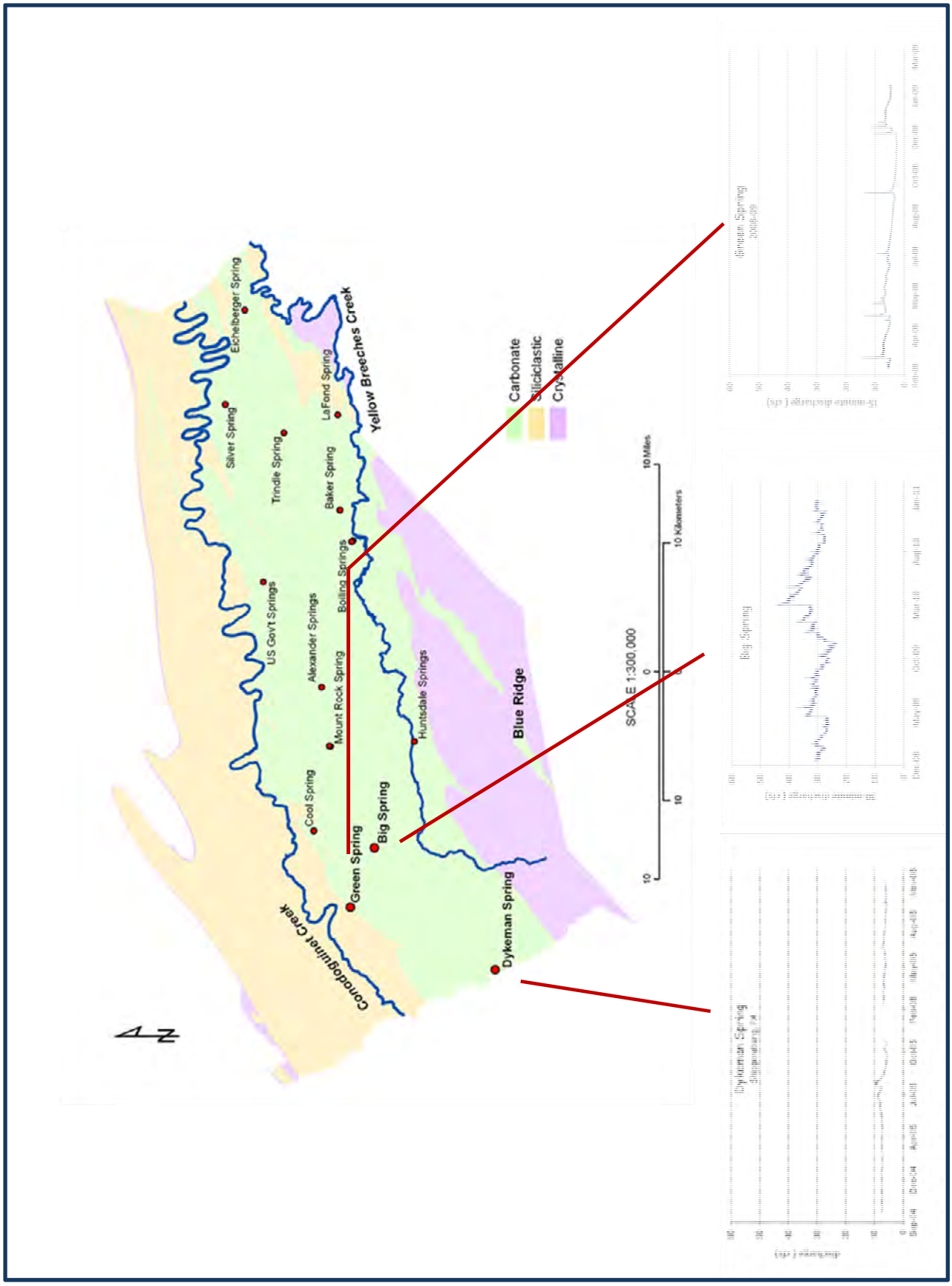


Figure 3. Comparison of 1-2 year hydrographs at Dykeman, Big, and Green Springs in Cumberland Co, Pennsylvania

Interestingly, the flow observed at Big Spring supports the developing model of a mantled karst in the Cumberland Valley where the colluvial apron extends from South Mountain toward the Valley axis, covering the carbonate sequence. In this model, Dykeman Spring, located in Shippensburg at the fringe of the colluvium has an extremely consistent flow; the high and low flow rainfall events are subdued by the porous colluvium. Big Spring, located further toward the Valley axis, exhibits greater fluctuation in flow due to the thinning of the colluvium and more rapid recharge through the karst. To further this example, flow from Green Spring is very flashy, revealing rapid response to rainfall events and a much smaller baseflow *(Figure 3)*. Green Spring is a contact spring located north of Big Spring at the Martinsburg Shale - Chambersburg Limestone contact. Discharge and specific conductance collected at 15-minute intervals over a 12-month period revealed a flashy hydrograph response indicative of a conduit flow aquifer *(Figures 3 and 4)*.

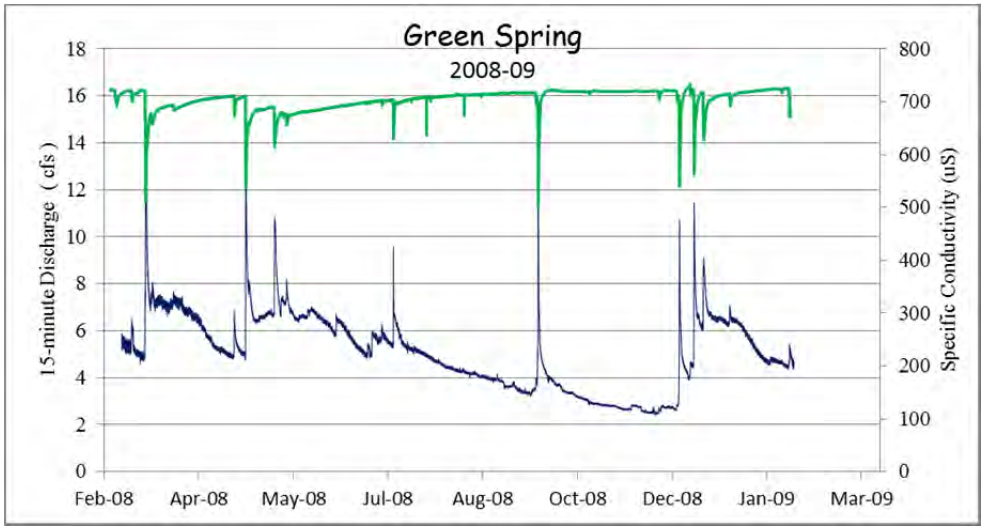


Figure 4. Discharge and Specific Conductivity of Green Spring demonstrating conduit flow characteristics.

Big Spring Dissolved Load

In June 2012 an InSitu® Troll100 was placed near the USGS gaging station to measure specific conductivity as a surrogate for disslved solids *(Figure 5)*. Specific conductivity during the six month period showed an average value of 450 µS, roughly 100 units greater than that observed at Dykeman Spring near Shippensburg and 200 units less than Green Spring. Although the dissolved load in Green and Dykeman springs show variation with recharge events, their specific conductance remains fairly constitant. Big Spring, however, reveals an oscillation of roughly 50 µS and a somewhat daily cycle. It is not clear why there is much more fluctuaton in the conductivity data at Big Spring than at Dykeman Spring. We recently received approval from the PA Fish and Boat Commission to place a probe directly at the spring head.

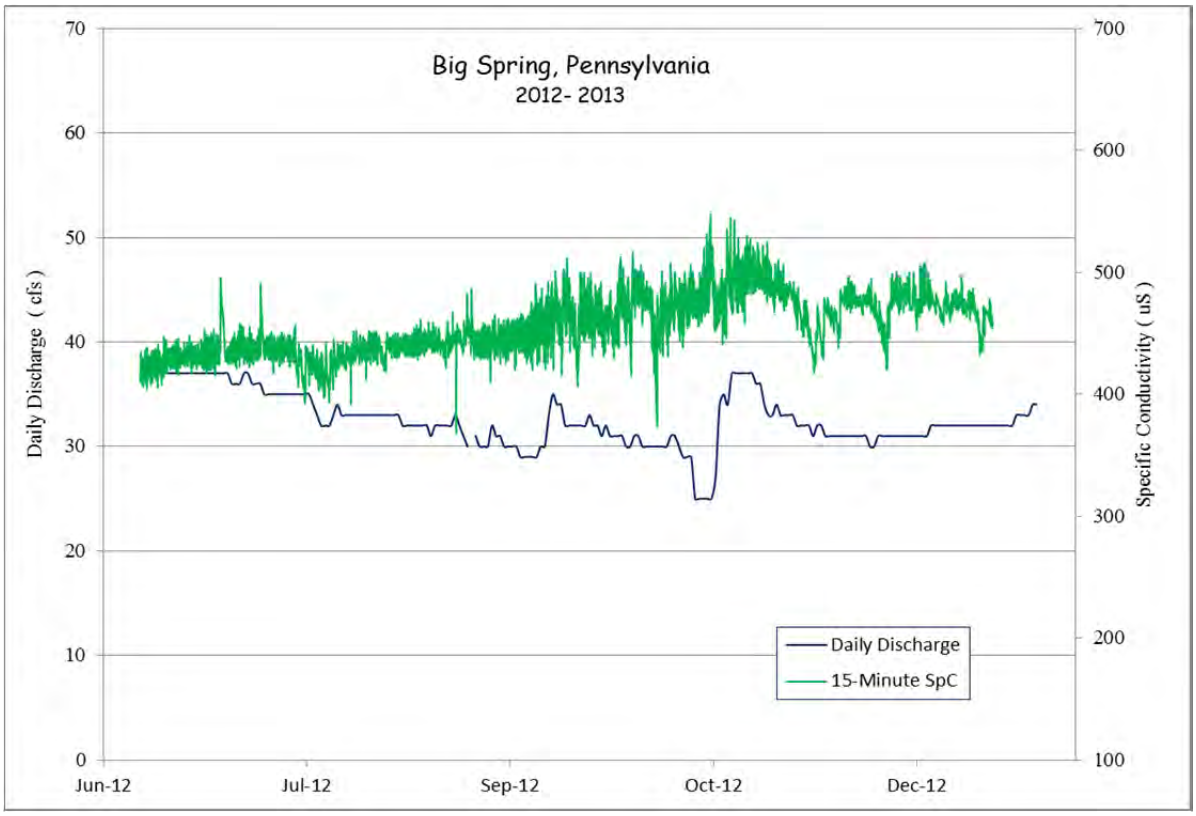


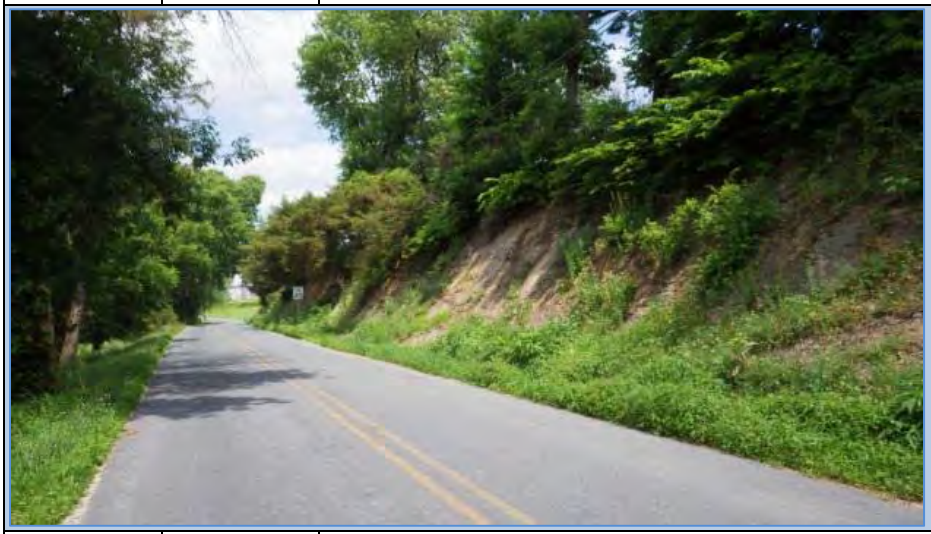
Figure 5.
Specific Conductivity reported in microSeimens at 25° C and USGS-measured discharge at Big Spring over a six-month period in 2012.
It is not clear whether the fluctuation in SpC is instrument-related or a function of the aquifer.

References

Becher, A. E. and Root, S. I., 1981, Groundwater and Geology of Cumberland Valley, Cumberland County, Pennsylvania: Pennsylvania Geological Survey, 4th Series, Water Resource Report W-50, 95 p.

Hurd,T.M., A. Brookhart-Rebert, T.P. Feeney, M.H. Otz, and I. Otz,, 2010, Fast, regional conduit flow to an exceptional-value spring-fed creek: implications for source-water protection in mantled karst of south central Pennsylvania: Journal of Cave and Karst Studies, v. 72, no. 3, p. 129–136.

Interval Mileage	Cumulative Mileage	**STOP = Stop Sign; = Traffic Light; "T" = T Intersection; TR = Township Route; "Y" = Y intersection**
0.0	18.5	Head north on Big Spring Road. Exposed rocks seen along the right side of the route are predominantly Ordovician Rockdale Run and St. Paul mapped units *(Becher & Root, 1981).* The flood plain and meandering course of Big Spring Creek along the route are the likely result of several former low-head dams, and their later removal, as well as the existing dam noted at mileage 22.4.
3.2	21.7	Enter Newville; ***continue slight right*** onto W Big Spring Avenue
0.2	21.9	STOP Cross Fairfield Street (PA Route 533); ***continue straight*** on W Big Spring Avenue
0.2	22.1	STOP ***Turn left*** onto S. High Street (PA Route 233)
0.1	22.2	***Turn right*** at onto Carlisle Road (PA Route 241)
0.2	22.4	Cross over Big Spring Creek; ***Note:*** *restored Laughlin Mill with dam and water wheel to the right*
1.1	23.5	***Turn half left*** onto Creek Road*; if you continue on Route 241 past a cemetery on the right, you have gone too far.*
1.4	24.9	STOP continue straight past "T" with Crossroads School Road
1.0	25.9	STOP contiue straight past Blosserville Road
1.9	**27.8**	Pass outcrop on right. This locality was described in the first edition of PA Geological Survey Report G40 "Fossil Collecting in Pennsylvania". The outcrop provides excellent examples of many genera found in the Chambersburg Formation. Later editions of G40 eliminated this locality. Known to collectors as the "Logan School" site, ***permission to collect here requires local owner agreement*.**

Interval Mileage	Cumulative Mileage	**STOP = Stop Sign; = Traffic Light; "T" = T Intersection; TR = Township Route; "Y" = Y intersection**
		**"Logan School" fossil collecting site in the Chambersburg Formation at mile 27.8**
0.2	28.0	Pass restored Heishman's Mill on left with low-head dam across the Conococheague Creek
0.1	28.1	STOP continue straight past "T" with Old Mill Road
0.8	28.9	***Turn right*** onto Bears Road; note quarry entrance dead ahead
0.05	**28.9+**	***ARRIVE*** **at off-loading site for access to Dickinson College quarry**
STOP 7. Dickinson College Quarry with rock trimming facility		

LiDAR image of Stop 7 – Dickinson College Quarry area, with geologic contacts overlain.

STOP #7 – DICKINSON COLLEGE QUARRY

(Access to this quarry requires signed liability waiver)

Stop Leader – Noel Potter, Dickinson College, Retired

Dickinson College Quarry with rock trimming facility

The Dickinson College Quarry (40°12'48.9"N, 77°17'49.8"W) (Fig. 1) is one of only a few limestone dimension stone quarries still operating in Pennsylvania. It was originally the Morrison Quarry, operated by 3 generations of that family since the early 1900's. In the 1960's it was purchased by Caretti, Inc., a masonry contractor in Harrisburg. In the late 1980's it was acquired by Dickinson College, which has several buildings made of stone from here.

Figure 1. Dickinson College Quarry, looking South. Note gentle dip down to left and thin partings along which rocks weather and break.

The quarry has also furnished stone for a number of the original Pennsylvania Turnpike service area buildings, at least from Midway to King of Prussia, and for the old Carlisle Hospital, now turn down and some of the stone salvaged and lying on the quarry floor awaiting re-use. A short history of the quarry is in Pennsylvania Geology (Anonymous, 1986). The quarry was briefly visited during the 1982 Field Conference (Stephens, et al., 1982, p. 54-55).

The quarry is in the Ordovician Chambersburg Formation, the youngest and topmost of the thick sequence of Cambro-Ordovician carbonate units in the Cumberland Valley. This is the last unit before deposition of the Martinsburg shale, which is exposed just north of the quarry across Conodoguinet Creek.

Figure 2.
Dickinson College Quarry, showing shaly partings along which rocks break, and a thin calcite vein.
Pencil for scale.

The limestone is a dark gray micrite with beds 10-25 cm thick separated by thin 1-2 cm thick shaly beds *(Fig. 2)*. There has been speculation over the years whether the shaly beds are episodic pulses of clay that were precursors to the overlying Martinsburg Formation. How long does it take for 10-25 cm of micritic limestone to be deposited? These clay pulses were clearly not very frequent events.

Bedding is oriented about *N15^{o}E, 20^{o}SE, indicating that* the quarry is near the hinge of a NE-plunging fold. Indeed Becher and Root (1981) have mapped the hinge of an anticline near here. Joints have a wide variety of orientations, but many trend about N45^{o}W and are near vertical. Some joints are calcite filled, and some calcite occurs along bedding planes with slickensides trending about N15^{o}W indicating flexural slip.

It is the thin shale partings along which the rock breaks to produce slabs that can be trimmed on the hydraulic guillotine into useable building blocks. The anonymous author (1986) of the Pennsylvania Geology article nicely summarizes the quarrying process and use of the stone:

> "Quarrying is done mostly by hand, initial benches are started by jackhammer drilling 1.5 inch-diameter holes about 4 feet deep on centers ranging between 2.5 feet and 4 feet parallel to the quarry face. Coarse-grained black powder charges (typically 10 to 20 ozs. in the bottom of the holes) are used as a blasting agent to reduce discordant fracturing free workable blocks along bedding within benches. Conventional drilling and blasting has been unsuccessfully tried. Pry bars and muscle are standard working tools. The ring of a hammer against a sound rock and a trained ear constitute quality control."

*Note from Noel: A few years ago the college hired a contractor to remove stone for a new building. The contractor used dynamite which produced many fractures in the stone and rendered it useless.

Slabs of stone are trimmed on the hydraulic guillotine—rectangular if the stone will be laid as ashlar *(Fig. 3)*, and irregular if it will be laid as rubblework *(Fig. 4)*. Fresh rock, when quarried is almost black; however after a few years of exposure to acidic rain the rocks turn to a mellow gray color.

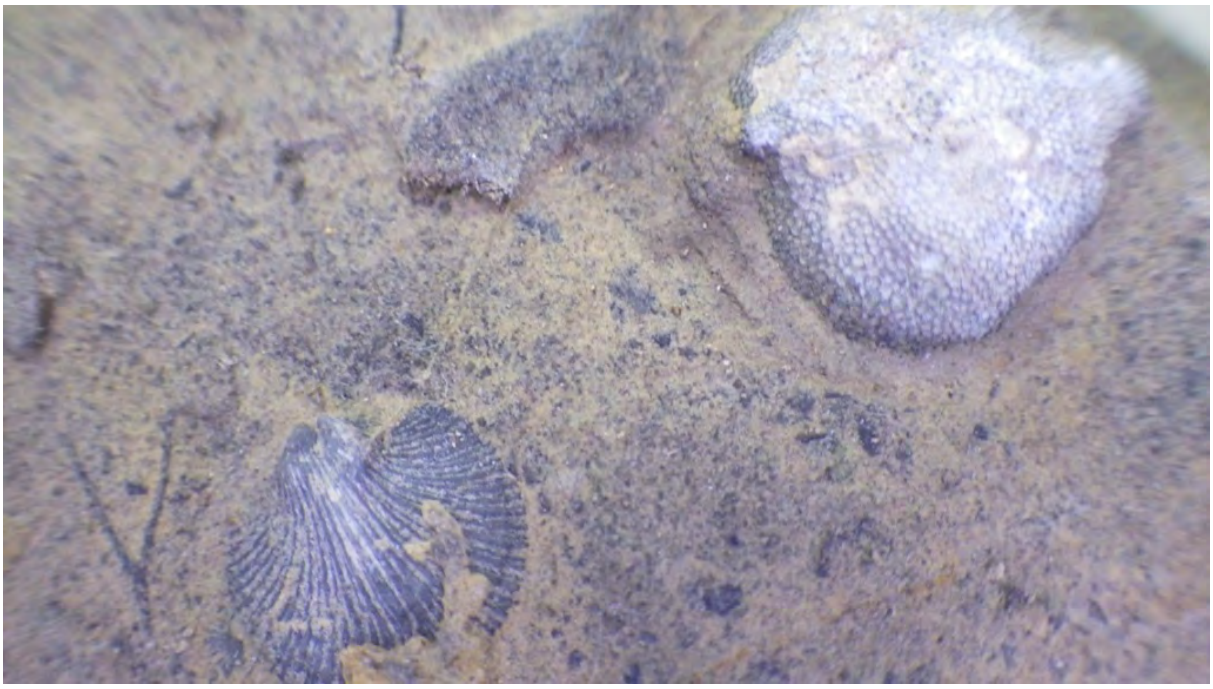
Figure 3. Stone laid in random-coursed ashlar.

Figure 4. Stone laid in irregular rubblework pattern.

Paleontology at Dickinson College Quarry

Fossils are present at Dickinson College quarry, but access requires College permission. Used as a teaching site by Dickinson College faculty, they request that samples indicated as teaching samples not be removed or damaged.

Fossils occur in very large blocks and as small, weathered, hand samples. Large blocks, if sufficiently weathered, provide opportunities for photographs. Samples for collecting may be found as small, loose blocks in material against the southern portion of the quarry and in a vegetation covered pile on the flat area above and to the east of the quarried part of the site. Piles along the east wall are not quarry stone but are waste material from other sites.



From lower left to upper right, small branching bryozoan, Orthid brachiopod and colonial bryozoans. The orthid brachiopod is penny sized.

The most common fossils are bryozoans and crinoid columnals. More rarely, brachiopods, gastropods and trilobites occur. Use hand lenses to view delicate features.

Branching bryozoans and single and conjoined crinoid columnals

Colonial branching bryzoans require hand lens to view zooecia

Branching and fan shaped bryozoans

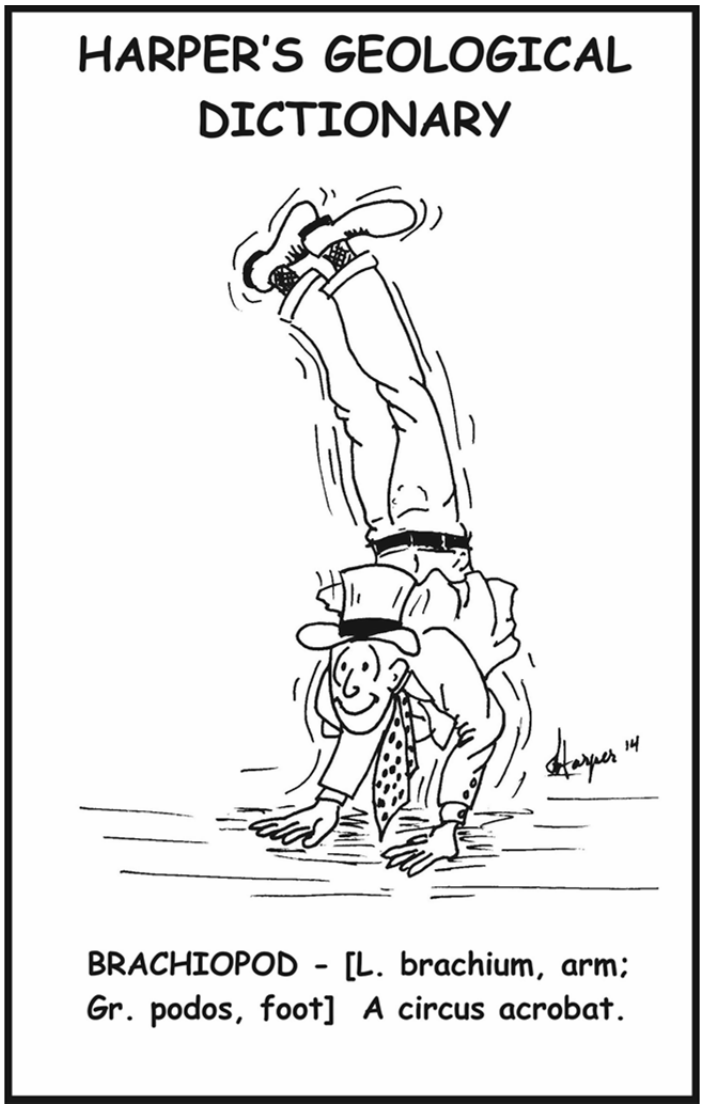
Bryozoans imbedded in large block show internal features

References

Anonymous, 1986, Building Stones from Cumberland County: Pennsylvania Geology, v. 17, no. 1, p. 10-12.

Becher, A. E. and Root, S. I., 1981, Groundwater and Geology of Cumberland Valley, Cumberland County, Pennsylvania: Pennsylvania Geological Survey, 4th Series, Water Resource Report W-50, 95 p.

Stephens, G. C., Wright, T. O., and Platt, L. B., 1982, Geology of the Middle Ordovician Martinsburg Formation and Related Rocks in Pennsylvania: Guidebook for the 47th Annual Field Conference of Pennsylvania Geologists, 87 p



Interval Mileage	Cumulative Mileage	**STOP = Stop Sign; = Traffic Light; "T" = T Intersection; TR = Township Route; "Y" = Y intersection**
0.0	28.9	Head south on Bears Road
0.6	29.5	Underpass under PA Turnpike
0.1	29.6	STOP ***Turn left*** onto PA Route 641 – Newville Road
2.7	32.3	Continue on PA 641 though Plainfield (on E. Main Street) to Meadowbrook Road; ***turn left*** before passing warehouse
0.6	32.9	Cross Conodoguinet Creek
0.1	33.0	STOP **"T"** ***Turn left*** on Meadowbrook Road (Dead-end Conodoguinet Avenue is to the right)
0.4	33.4	Exposures of the lowermost autochthonous Martinsburg shale on right in road bank. Although covered by vegetation, bedrock here dips steeply north with prominent south dipping cleavage. Mapping by Becher & Root, 1981 locates the contact with underlying Great Valley carbonates at this mileage.
0.5	33.9	Continue to "T" intersection with Creek Road STOP; ***turn right*** on Meadowbrook Road. The outcrops for the last 0.5 mile are Martinsburg shales with prominent south dipping cleavage and less apparent open folds stratigraphically above a northeast plunging carbonate anticline located west of the Conodoguinet Creek paralleling the route.
		Anticline in the lowermost Martinsburg Formation shales between mileages 33.4-33.9
0.1	34.0	***Turn right*** on Willow Grove Road
0.6	34.6	STOP Cross McClures Gap Road; continue straight
1.0	35.6	STOP ***Turn right*** onto Easy Road
0.8	36.6	STOP ***Turn left*** onto Pa Route 74
0.2	36.8	***Turn right*** on N. Middleton Road in community of Caprivi
0.3	37.1	Arrive at access road to N. L. Minich & Sons quarry; ***turn left***
0.1	**37.2**	***ARRIVE*** **at off-loading site in the Minich quarry**

LiDAR image of Stop 8 – Minich Quarry. Image with geologic contacts overlain shows area of autochthonous Martinsburg Formation (Om)

STOP #8 – AUTOCHTHONOUS MARTINSBURG FORMATION

(Access to this quarry requires signed liability waiver)

Stop Leader – Donald Hoskins, PA Topo & Geologic Survey, Retired

Entrance to N. L Minich & Sons, Inc. shale pit at Caprivi

Shales and greywacke sandstones underlie nearly half of Pennsylvania's Great Valley Province. Recognized as a separate lithologic unit in 1824 by William Darby, a surveyor and traveler, he then published a page-sized, hand-colored map of Pennsylvania delineating the shales and sandstones of the Great Valley as well as other units. For additional information on this map, see the brief chapter and reproduction of Darby's map in the full guidebook.

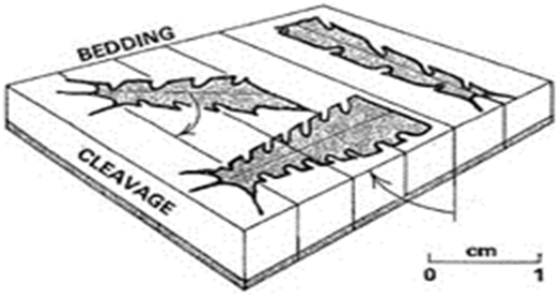
Named for the shale hills near Martinsburg, West Virginia, *(Keith, 1894)* the formational name was extended into and through Pennsylvania and south through Virginia into Tennessee. Generally poorly exposed and possessing rock types of little economic value not much attention has been paid to the Martinsburg west of the Susquehanna River. Two reports, Geology and Mineral Resources of Northeastern Franklin County, Pennsylvania *(Root, 1971)* and Groundwater and Geology of the Cumberland Valley, Cumberland County, Pennsylvania *(Becher and Root, 1981)* are the only ones describing and mapping the autochthonous Martinsburg in the area of the 2014 Field Conference. The Cumberland County report also describes and maps allochthonous Martinsburg which includes rocks whose lithologies are markedly different from the rock types of the original type area.

The Minich pit (40°14'50.6"N, 77°13'46.9"W) provides attendees an opportunity to examine autochthonous rock types of the classical "Martinsburg". Stop 9 will address the allochthonous rock types that extend west of the Susquehanna River.

The Minich pit extends in a northerly direction approximately 2500 feet that is nearly perpendicular to regional strike. Nearly 100% of the lithology is shale; only two thin greywacke sandstones occur in the pit as of this writing. The rocks are deeply weathered with relatively "fresh" rock seen only in the southern portion of the pit.

The shales are overturned and dip steeply south to vertical. Cleavage is pervasive in the rocks and also dips south producing excellent examples of pencil shale. Jointing is also pervasive with the J2 direction visible in unweathered rock. The J1 direction is seen in highwalls as nearly horizontal.

Fossils are present in this pit. Graptolites of at least three genera are present and date the Minich pit rocks as Middle Ordovician *(Robert Ganis, personal communication)*. The collected specimens all have come from loose material at the base of the uppermost highwalls where they most easily appear on light colored chips. The chips have not been traced back to specific layers exposed in the highwalls. Stephens and Wright (1981) in their examination of the Martinsburg stratigraphy and paleontology west of the Susquehanna River identified these rocks as the "Lower Shale" unit and in the *Diplograptus multidens* Zone of Riva (1969). Although not observed to date in the Minich pit, Stephens and Wright report additional graptolite genera as well as several genera of shelled fauna to be present in the "Lower Shale" lithology.



Relation of graptolites on bedding planes to shortening across cleavage. Graptolites parallel to the trace of cleavage on the bedding are narrower than normal, and those perpendicular to the cleavage trace are shorter. Figure is from Wright and Platt (1982) Figure 2"

Strain measurement of Martinsburg graptolites in the Great Valley from Carlisle southwest into Virginia establishes that pressure dissolution of calcite and silicate minerals removed half of the formation's original rock volume (Wright and Platt, 1982).

References

Becher, A. E. and Root, S. I. 1981, Groundwater and Geology of the Cumberland Valley, Cumberland County, Pennsylvania. Pennsylvania Geological Survey, 4th ser., Water Resource Report 50

Keith, A., 1894, Harpers Ferry, Va.-W.Va.-Md. U. S. Geological Survey, Geological Atlas, Folio 10

Root, S. I. 1971, Geology and Mineral Resources of northeastern Franklin County, Pennsylvania, Pennsylvania Geological Survey, 4th ser., Atlas 119ab

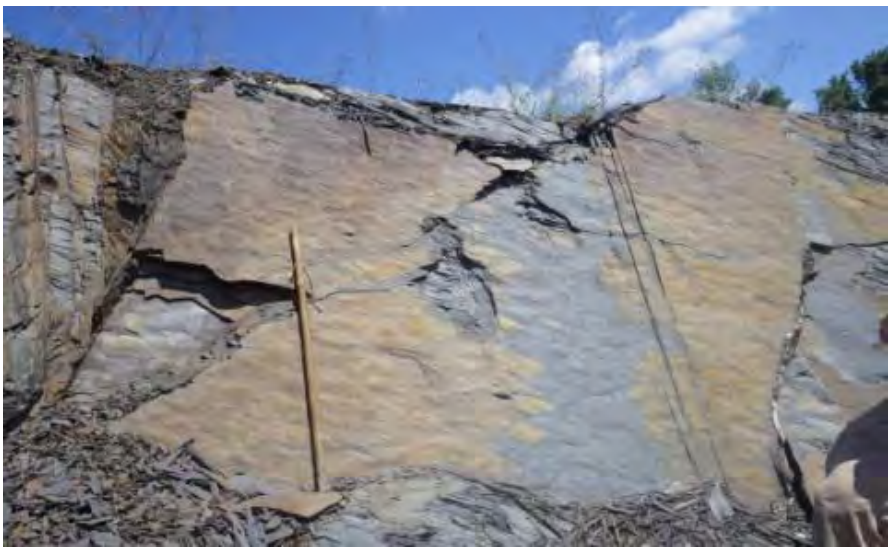
Stephens, G. C. and Wright, T. O. 1981, Stratigraphy of the Martinsburg Formation, west of Harrisburg in the Great Valley of Pennsylvania., American Journal of Science, Vol. 281, October 1981,p 1009-1020.

Wright, T. O. and Platt, L. B. 1982, Pressure dissolution and cleavage in the Martinsburg shale, American Journal of Science, Vol. 282, February 1982, p. 122-135.

Specific features to be seen at Stop 8 are described in the following photographs:

View of uppermost highwall at Minich pit. Graptolites occur in loose fragments in piles along the highwall base. Pick a pile, sit down, and using land lens look for tiny, very dark stripes on light shale chips.

Intersection of vertical to steeply south dipping layering (paralleling the one meter long walking stick) with less steeply south dipping cleavage (paralleling the rock hammer handle)

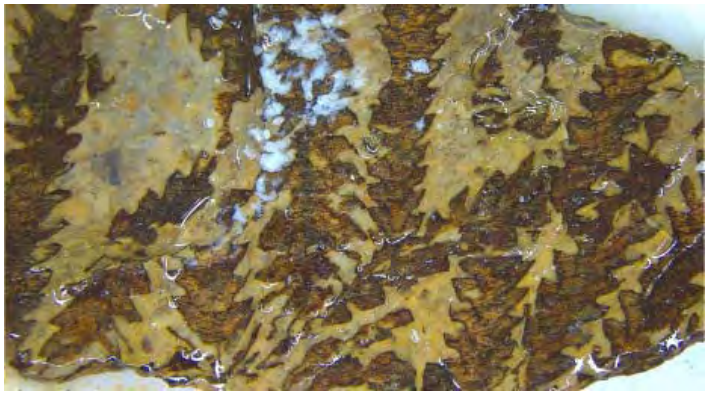


Exposed rippled bedding plane with J2 joints present along left edge and to the right. Ripples imply flow direction toward viewer. One-meter stick provides scale

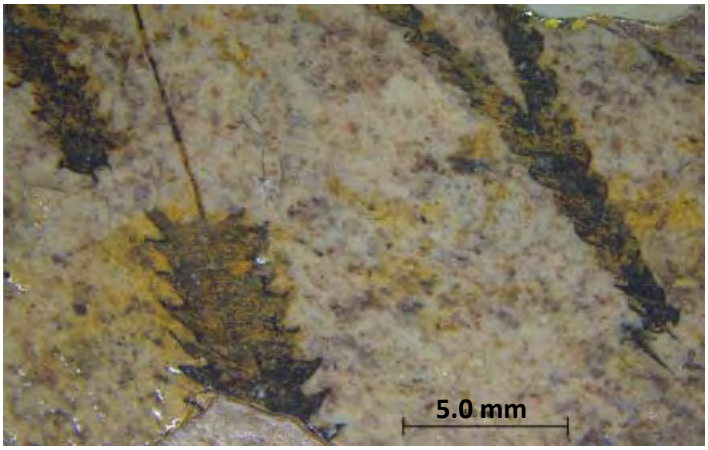
Left side of view shows nearly vertical brownish layer surface with intersecting south dipping cleavage plus J2 joints producing pile of pencil cleavage on right. In center is J2 joint filled with calcite vein.

Overturned, south dipping greywacke sandstone and siltstone at Minich pit

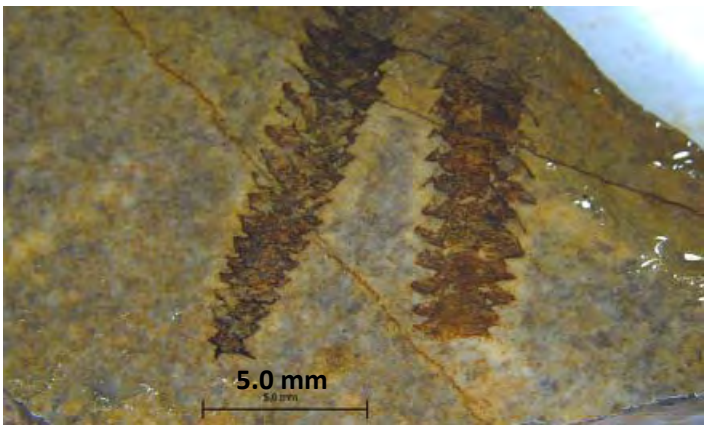
Group of genus *Amplexograptus* at Minich pit



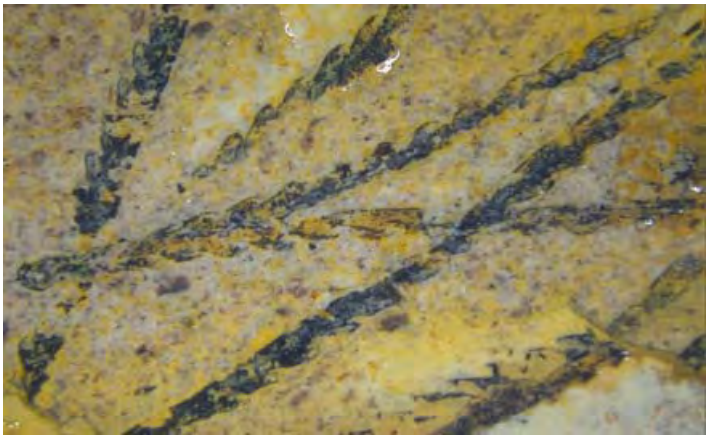
***Dicranogaptus* (right) and *Amplexogratus* (lower left) at Minich pit**



***Amplexograptus* at Minich pit**



***Dicranograptus* at Minich pit**



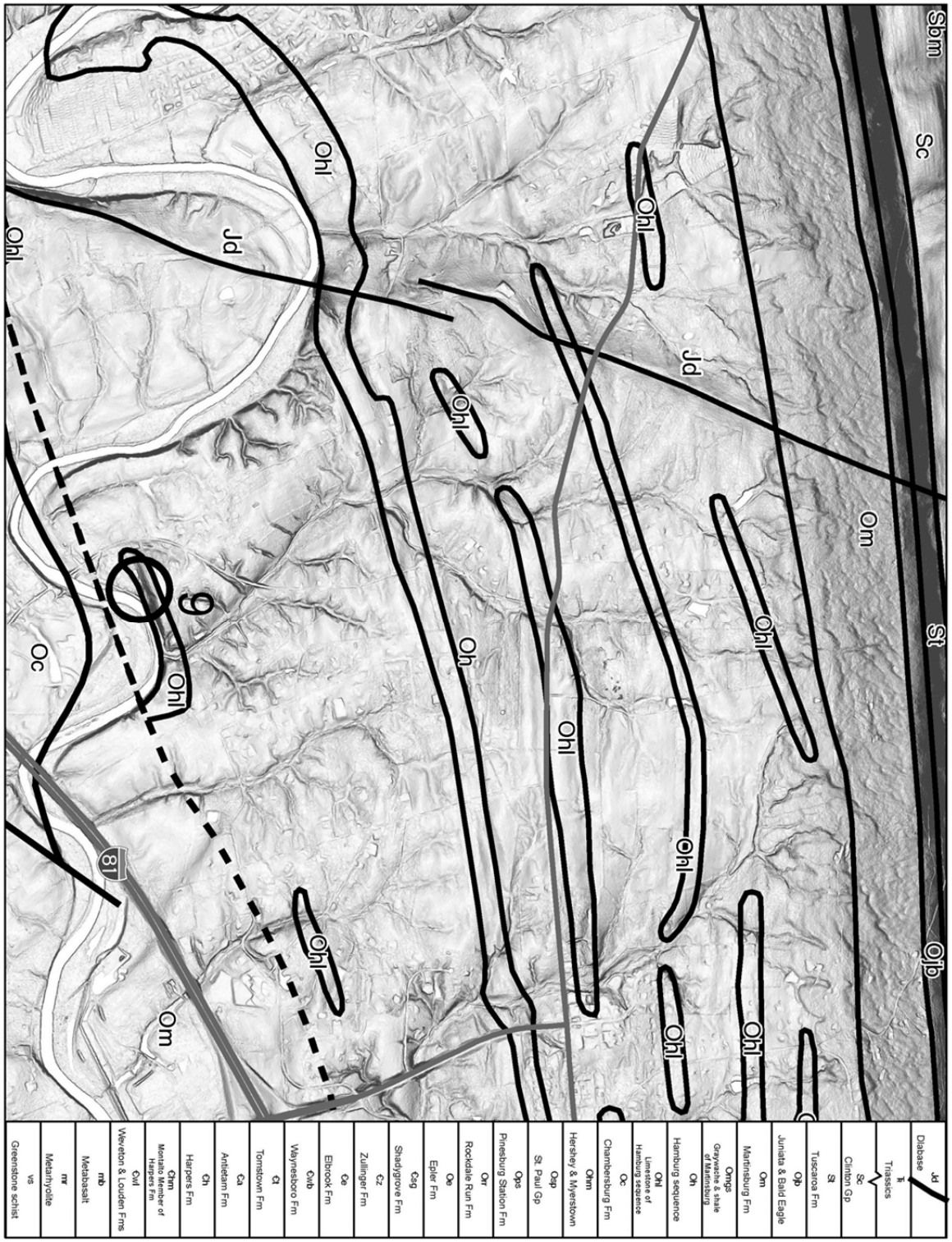
Interval Mileage	Cumulative Mileage	**STOP = Stop Sign; = Traffic Light; "T" = T Intersection; TR = Township Route; "Y" = Y intersection**
0.0	37.2	Return on access Road to N. Middleton Road; turn right toward Caprivi
0.3	37.5	STOP ***Turn left*** onto PA Route 74 S – Waggoners Gap Road
1.0	38.5	***Turn left*** into North Middleton Park
0.1	**38.6**	**Continue to lower level to pavilion area – Stop for LUNCH**

NORTH MIDDLETON TOWNSHIP PARK
DAY 2 LUNCH STOP

Aerial view of North Middleton Park
flooded because of 1972 Hurricane Agnes
Lunch will be served in the pavilion denoted by the yellow arrow.

Photo by Noel Potter

Interval Mileage	Cumulative Mileage	STOP = Stop Sign; = Traffic Light; "T" = T Intersection; TR = Township Route; "Y" = Y intersection
0.0	38.6	Return to entrance of N Middleton Park
0.1	38.7	***Turn right*** onto PA Route 74 – Waggoners Gap Road
3.2	41.9	***Turn right*** onto PA Route 944 E – Enola Road
5.2	47.1	STOP Intersection with PA Route 34; ***turn left*** to continue on PA Route 944 E and PA Route 34 (Spring Road) combined
0.3	47.5	***Turn right*** onto Wertzville Road – PA Route 944 E, continue past two bends to next **"T"** intersection
3.2	50.7	STOP **"T"** ***turn right*** onto PA Route 944 E – Wertzville Road
1.2	51.9	Cross Deer Lane (***underlain by Triassic diabase dike***); continue on Wertzville Road
0.9	52.8	***Turn right*** on Rich Valley Road
1.0	53.8	***Turn left*** on Beechcliff Drive
0.4	54.2	**"T"** intersection; continue to the right on Beechcliff Drive
0.1	**54.3**	***ARRIVE*** **at off-loading site for Enola Allochthon – Stop 9**



LiDAR image of Stop 9 – Enola Allochthon. Image with geologic contacts overlain shows allochthonous "Hamburg Klippe" (Oh) of Stose (1946). Shales and mudstones (Oh) interbed and encase the limestones (Ohl). Dashed line to the south and solid line to the north represent the divide between autochthonous Martinsburg Fm (Om) and allochthonous "Martinsburg". Ganis and Blackmer (2010) propose new interpretations for these old terranes.

STOP #9 – ENOLA ALLOCHTHON

Stop Leader – Donald Hoskins, PA Topo. & Geologic Survey, Retired

Isoclinal folds in discontinuous thin limestone layers of the Enola Allochthon (Root & MacLachlan, 1978, GSA Bull., pp. 1515-28)

The rocks of the autochthonous Martinsburg Formation seen at Stop 8 extend southwest along the Great Valley Section of the Appalachians Ridge and Valley Province into West Virginia and Virginia. Stop 9 (40°15'46.6"N, 77°4'30.5"W) represents allochthonous rocks markedly distinct in both lithology and geologic structure, yet possessing the same topographic expression long recognized as part of Pennsylvania's Great Valley. The geologic description of Stop 9 derives largely from Dyson (1967) and Root and MacLachlan (1978).

Exotic rock types have long been known to occur in a portion of the Great Valley Section that extends from northeast of Carlisle eastward to just beyond the county boundary between Berks and Lehigh counties. Stose (1946) recognized the allochthonous nature of these rocks and named them the "Hamburg Klippe." The allochthonous rocks include chert, limestones, red and green mudstones and volcanic rocks. Prior Field Conferences (2010, 1984, and 1982) examined these rocks mainly east of the Susquehanna River. The 2010 Field Conference Guidebook included a preliminary geologic map (Ganis and Blackmer, 2010) of the rocks of the northern part of the Great Valley in Dauphin and Lebanon Counties. Newly mapped Dauphin and Linglestown Formations in this map replace the "Hamburg Klippe"'s regional mapping and interpretations.

Root and MacLachlan (1978) identified and mapped terranes west of the Susquehanna as allochthons and wildflysch containing rocks that include reddish mudstones and gray limestones enclosed in greenish and greenish gray shales and mudstones as well as dark gray to black mudstones. These rocks are included in their "Enola Allochthon". Of limited lateral extent they extend from the Susquehanna River (Root, 1977) to Carlisle (Dyson, 1967) where they locally are conglomeratic and arenaceous. The limestones, generally less than 6 m thick, are composed of thin layers of platy weathering, dark-gray, micritic, argillaceous limestones. Some of the thicker layers contain oolites and large quantities of rounded, totally transparent, pure quartz. Thin to massive layers of black, limy shale, such as is present at this Stop, interbed or encase the limestones.

Isoclinally folded Enola Allochthon limestones at Beechcliff Drive at or near the site of Root and MacLachlan's (1978) Figure 7

Rocks of similar lithology exposed in relatively nearby areas east of the Susquehanna (Ganis and others, 2001) contain graptolites and conodonts dated as Lower to Middle Ordovician. They interpret that those sediments "were consolidated and incorporated as olistoliths in an olistostrome, possibly as a trench-fill complex during the Middle Ordovician." More recent explanations of the geologic history of these rocks that apply to Stop 9 rocks are in Ganis and Blackmer Stop 10 (2010) and Ganis and Blackmer (2010).

The exposures along Beechcliff Drive are replete with overgrowth and somewhat difficult to access. Hand samples abound at the foot of the steep sided outcrops. Stop 9 exhibits only the thin limestones and interbedded black to dark gray shales which have been extensively folded in small, tight chevron zones and crushed as broken clasts. At the far eastern end of the exposure are south dipping siltstones with prominent orthogonal jointing and cleavage. The strike of these rocks parallels that of layers seen in the bottom of the adjacent Conodoguinet Creek.

Features to be seen in exposures along Beechcliff Drive, Stop 9:

Hand sample of tight chevron style folding at Beechcliff Drive

Hand sample of crushed and rounded limestone layers in clay matrix at Beechcliff Drive.

Stretched and fragmented thin limestone layers at Beechcliff Drive.

South dipping layers at easternmost portion of Stop 9 on Beechcliff Drive

CAUTION*: this portion of the outcrop at Stop 9 is immediately adjacent to a blind traffic corner. The pavement extends within a few inches of the base of the outcrop. Traffic arriving from the right may not see you!*

References

Dyson, J. L. 1967, Geology and mineral resources of the southern half of the New Bloomfield quadrangle, Pennsylvania, Pennsylvania Geological Survey, 4th series, Atlas 137cd.

Ganis, G. R. and H. C. Blackmer, (2010) Stop 10: Sports City, Linglestown-Shellsville olistostrome, *in* Wise, D. U. and G. M. Fleeger, eds., Guidebook, Tectonics of the Pennsylvania Piedmont along the Susquehanna River, 75th Annual Field Conference of Pennsylvania Geologists, Lancaster, PA, p. 87-89.

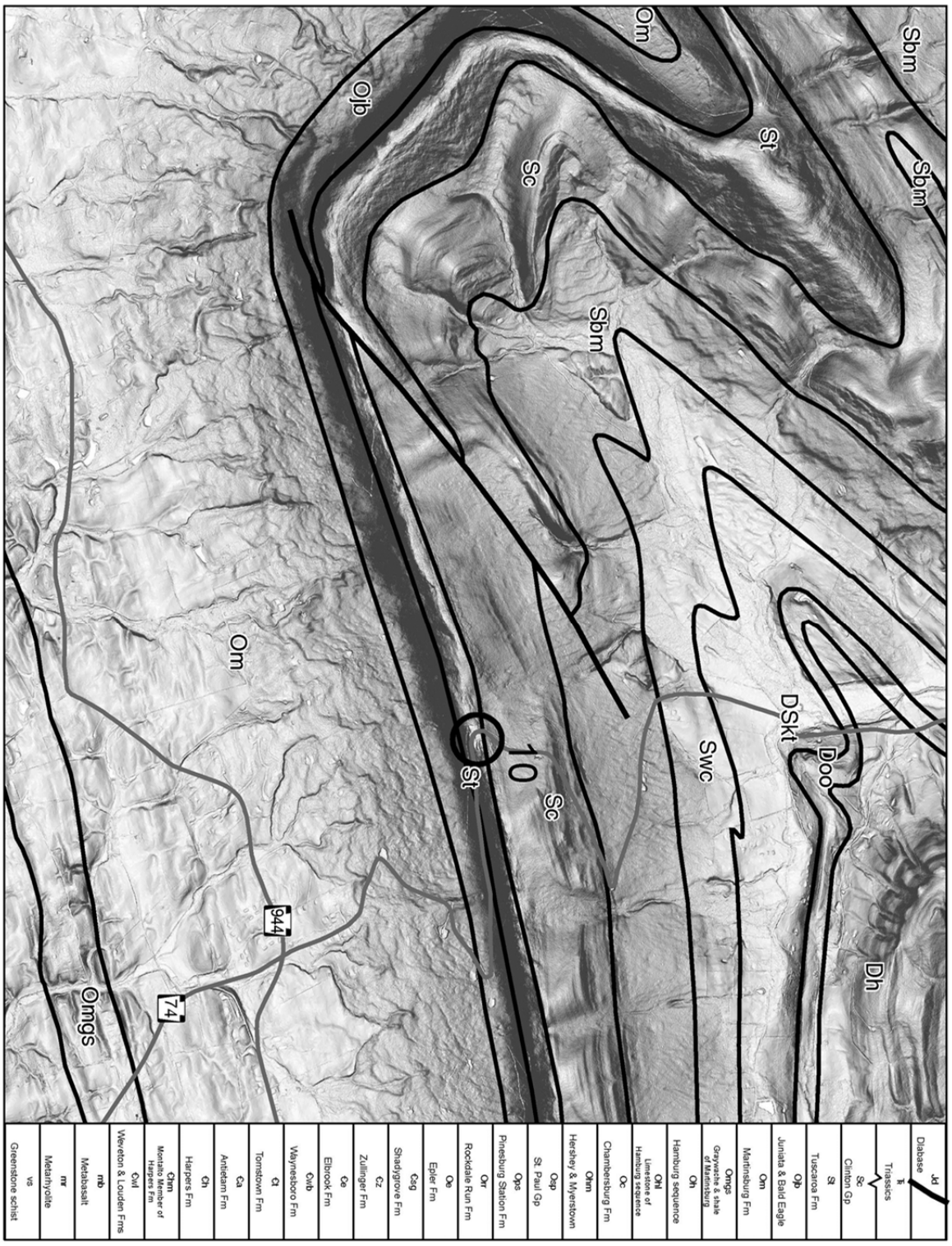
Ganis, G. R. and G. C. Blackmer, 2010, Taconic foreland basin and allocthons, in Wise, D. U. and G. M. Fleeger, eds., Tectonics of the Susquehanna Piedmont in Lancaster, Dauphin and York counties, Field Conference of Pennsylvania Geologists, p. 67-75

Root, S. I., 1977, Geology and mineral resources of the Harrisburg West area, Pennsylvania Geological Survey, 4th series, Atlas 147c-148ab

Root, S. I and D. B. MacLachlan, , 1978, Western limit of Taconic allochthons in Pennsylvania, Geological Society of America Bulletin, v.89, p. 1515-1528.

Stose, G. W., 1946, The Taconic sequence in Pennsylvania, American Journal of Science, v. 244,p. 665-696

Interval Mileage	Cumulative Mileage	**STOP = Stop Sign; = Traffic Light; "T" = T Intersection; TR = Township Route; "Y" = Y intersection**
0.0	54.3	Drive west on Beechcliff Drive
0.3	54.6	STOP ***Turn right*** on Rich Valley Road
1.7	56.3	STOP ***Turn left*** on Pa Route 944 W – Wertzville Road
2.0	58.3	***Turn left*** continuing on PA Route 944 W – Wertzville Road
1.5	59.8	At **"Y"** junction, bear left continuing on PA Route 944 W
1.7	61.5	At **"T"** junction, bear left continuing on PA Route 944 and PA Route 34S
0.3	61.8	***Turn right***, continuing on PA Route 944 W; Road name changes to Enola Road
5.3	67.1	STOP ***Turn right*** onto Pa Route 74 – Waggoners Gap Road
0.3	67.4	Blocks of Juniata and Tuscorora Formations present on both sides of route indicating local colluvium derived from Blue Mountain
0.3	67.7	On right is example of American culture
0.1	67.8	On left the soil in the cut bank behind North Mountain Inn was described by Edward Ciolkosz (Pennsylvania State University) published in Sevon (1989, p 40-42 and 2001, p. 83-86). Briefly, the soil in the colluvium at this site "is a composite with a weakly developed Wisconsinan upper profile and a much better developed truncated buried lower pre-Wisconsinan profile (at 325 cm)."
1.7	**69.5**	***ARRIVE*** **at off-loading site for Waggoner's Gap – Stop 10**



LiDAR image of Stop 10 – Waggoners Gap area, with geologic contacts overlain

STOP #10 – WAGGONERS GAP

Stop Leaders: Donald Hoskins, PA Topo & Geologic Survey, Retired

Stratigraphy – Tuscarora & Juniata Outcrops

Dorothy Merritts, Franklin & Marshall College

LIDAR Interpretation of Area's Colluvial Slopes

Noel Potter, Dickinson College, Retired

Geomorphology and Lesley's Structural Interpretation of the Great Valley

The Great Valley Physiographic Province from Waggoners Gap

Contact of the Silurian Tuscarora & Ordovician Juniata Formations at Waggoners Gap

Last visited by the *Field Conference of Pennsylvania Geologists (FCOPG)* in 1982, we again chose this site (40°16'36.9"N, 77°16'36.7"W) for the opportunity to observe the geomorphology of the Great Valley, and to examine the stratigraphy and sedimentology of the Tuscarora and Juniata Formations. Tuscarora rocks support the crest of Blue Mountain and many of Pennsylvania's high ridges that dominate the geomorphology of the Appalachian Mountain Section of the Valley and Ridge Province. Exceptionally well exposed here is the underlying Juniata Formation, rarely seen on these ridges due to extensive colluvial cover.

The ridge and highway outcrops and the colluvial-covered slopes to the highway at Stop 10 are presently the property of, and managed by, the Audubon Society as the "Hawk Watch at Waggoners Gap". Please respect the property and signs as well as the Hawk Watch teams that you may encounter. Do not attempt to collect mineral specimens.

In May 1982, the *Society of Economic Paleontologists and Mineralogists – Eastern Section (SEPM-ES)* examined these rocks under the leadership of Edward Cotter, PhD, and Professor at Bucknell University. The October 1982 FCOPG Guidebook quoted much of Dr. Cotter's SEPM-ES text as the bulk of its Stop 4 description. With the permission of Dr. Cotter, his stop description and illustrations from the 1982 SEPM-ES

Guidebook *(pages 3 and 63–68)* are included as Appendix A to this road-log section of the 2014 FCOPG Guidebook.

Dr. Cotter's interpretations remain valid. In brief, deposited in braided river systems both the Juniata and overlying Tuscarora Formations were similar in origin. They differ partly in color and in their resistance to erosion. Additionally, here, and along Blue Mountain to the east, the basal 30 meters of Tuscarora represent a transgressive event producing a beach sequence along a retrograding coast. New full-color photographs are provided of features he figured.

Since 1982 additional work, as well as the newly availability of LIDAR imagery, allow additional geological interpretations to be made of the exposed rocks and of the land surface here and nearby to this site.

Present as thin films on joint surfaces approximately 2 meters above the base of the Tuscarora's beach sand sequence are patches of supergene phosphates. Robert Smith *(personal communication)* states: "The main secondary (supergene) phosphate at Waggoners Gap is variscite. Specifically, it is the 'Lucin-type'… . Associated minerals at Waggoners Gap include pale green, chalky wavellite and trace green turquoise."

"The Mineralogy of Pennsylvania 1966-1975" *(Smith, 1982, p. 269-274)* provides a full description of these mineral occurrences at Waggoners Gap. The hardness of the rocks also mitigates collecting of specimens.

North dipping Tuscarora sandstone at the crest of Blue Mountain viewed from the Hawk Watch platform.

Stratification in the Tuscarora's basal horizontally laminated lithofacies (interpreted as beach origin) approximately 15 meters above formation base. This figure is ~= to Cotter's 1982 Figure 26 A.

Symmetrical ripples on layer base in upper right area of photo. This figure includes Cotter's 1982 Figure 26 B. Note that the larger scale ripples occur on the underside of layers in the lower left side of this photo, indicating two additional flow directions.

Basal lag gravel in the lowermost layer of the Tuscarora Formation's cross-laminated lithofacies.

This photo ~= Cotter's Figure 26 C

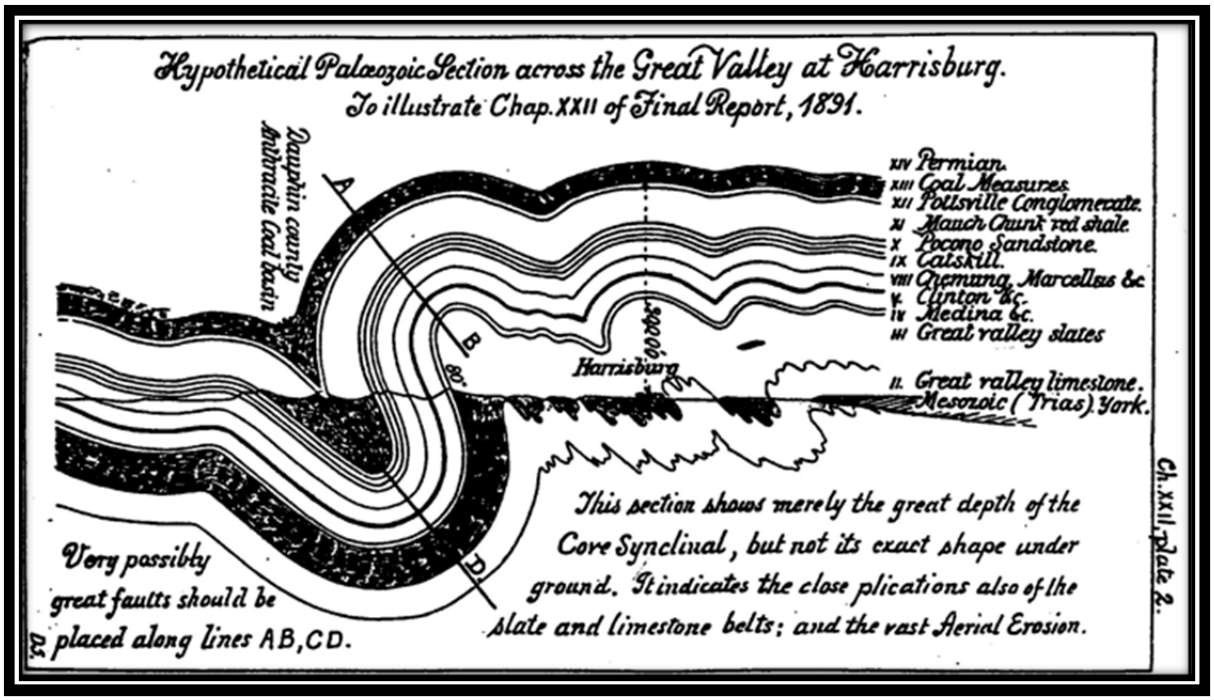
Trough cross-laminated Tuscarora sandstone with red shale clasts.

This photos ~= Cotter's Figure 26 D

Contact of the Tuscarora and Juniata Formations at Waggoners Gap.

Interpreted as laminated beach deposits, the light colored layers of the Tuscarora exhibit neither cross layering (except in the lowermost two layers at the waist level of Shippensburg student Alex Suder) nor shale interlayers of the reddish Juniata Formation at the right side of the photo. Alex stands on the contact of the two formations.

Pennsylvania's Great Valley Section of the Ridge and Valley Province at Waggoners Gap



Cross section, looking East, across the Great Valley at Harrisburg, PA as envisioned by J. P. Lesley, 1892. This is a reasonable representation of the large amount of rock that has been eroded since the end of the Alleghanian orogeny 250 + 10 ma. This cross section constructed by a very astute geologist lacks only an indication of the very large thrust faults that carried material northwest over the Anthracite Basin. The nature of this thrusting was only understood during the latter part of the 20th century (from Sevon, 2001)

Interpretation of red shale clast origin and topography of red shale interlayers – an exercise in visualization

Reddish shale interlayers occur between many of the prominent sandstone layers that make up the bulk of the Juniata Formation exposures along the highway at Waggoners Gap. Weathering more rapidly than the sandstone layers, the shale layers are thin, recessed and difficult to examine. Originally deposited as reddish mud, they apparently became consolidated sufficiently to be eroded and be re-deposited as clasts that frequently occur within the cross-layered sandstones and, in a few examples, emphasize the cross layering. Similar red clay clasts occur in the lowermost cross-laminated layers of the Tuscarora above the beach sand facies. But, in this formation, the few shale interlayers observed are gray, not red. Where do these Tuscarora clasts originate?

Red mud clast included with gravel in cross-layered Juniata Formation sandstone at Waggoners Gap. Similar red clasts occur in Tuscarora layers.

Red mud clasts paralleling cross layering in Juniata Formation sandstone at Waggoners Gap

Additionally, clay interlayers developed topography of lumps, ripple marks, and miscellaneous surfaces that now reflect themselves as the mirrored topography seen on the underside of the overlying sandstone layers. The mud layers were also the likely site of burrowing biotic activity producing tubular features now exhibited mainly as raised features on the undersides of overlying sandstone layers.

Burrow, likely Arthrophycus, and cavities on base of a Juniata sandstone layer at Waggoners Gap

Note the burrow stands in relief while the cavities are depressed into the lower surface of the sandstone layer. This vertical topography of the now absent clay layer may be deposits of burrower-ingested sediment. The depositional surface of the sandstone was relatively rugged. These surfaces are a common sight at Waggoners Gap. Some depressions on these surfaces retain the red clay of the now absent interlayer.

Are the burrows Arthrophycus?

Burrows on the base of a Tuscarora Formation layer at Waggoners Gap

Note that the burrows stand in relief on the layer base implying that the sand filled exposed or collapsed burrows in the underlying mud at the depositional surface. Most burrows do not retain fine details. Thus, identifying these to generic or specific detail is difficult without very close examination. At Waggoners Gap one small surface with the typical annulations of *Arthrophycus alleghenyensis occurs,* allowing, by extrapolation, to identify all other burrows by this classic name.

Supergene phosphates at Waggoners Gap

(e-mail notes from Robert Smith, PA geological Survey, Retired)

"As far as I know, the first recorded recognition of phosphates at approximately this horizon was by Jack B. Epstein (1967 Subitzky volume part covering Shawangunk Formation). He found and described carbonate fluorapatite nodules. Many years later John H. Way and I found carbonate-fluorapatite nodules in Shawangunk/Tuscarora outcrop near Rockville on the east side of the Susquehanna, Blue Mountain, Dauphin County. These sedimentary nodules are very likely the "primary" source for the secondary (supergene) phosphates long known from Blue Mountain, Cumberland County."

"The main secondary (supergene) phosphate at Waggoners Gap is variscite. Specifically, it is the "Lucin-type. … Associated minerals at Waggoners Gap include pale green, chalky wavellite and trace green turquoise. The same species have been verified in the Sterretts Gap area. The vast majority of the green and greenish minerals at both localities are variscite, not turquoise …"

***Variscite* exposed as a film on joint surface of the "beach sand" facies of the Tuscarora Formation at Waggoners Gap**

Supergene minerals are present at Waggoners Gap on the joint surface at Shippensburg student Alex Suter's eye height

Vertical biogenic structures at Waggoners Gap

Vertical biogenic structures occur in the Juniata Formation at Waggoners Gap. These structures occur in the layers immediately above a culvert, approximately midway in the Juniata Formation exposures.

Anne Kuebler's 1982 thesis at Bucknell University "*Trace Fossils in the Juniata Formation in Central Pennsylvania suggest Earliest Land Life in Late Ordovician Time*" describes and interprets biogenic structures that occur at Waggoners Gap in the Juniata layers as ""essentially vertical, poorly defined, red clay-filled burrows" that she interprets as "evidence for earliest land life in Late Ordovician Time" (Kuebler, 1988 p. iv).

Red mud filled vertical burrows in the Juniata Formation at Waggoners Gap

Close up image of vertical burrows in gravelly sandstone of the Juniata Formation at Waggoners Gap

APPENDIX A. WAGGONER'S GAP IN BLUE MOUNTAIN

(reprinted with author's permission from Cotter, Edward, "STOP 2. Waggoner's Gap in Blue Mountain", SEPM-ES Guidebook, May 1982, p.3; pp. 63 – 68.)

Horizontally laminated (beach) lithofacies overlying Juniata Formation and underlying eastern cross-laminated (braided fluvial) lithofacies

The Tuscarora Formation here forms the southeasternmost ridge in the Valley and Ridge geomorphic province, and this outcrop is the most proximal section of the formation we shall see on this trip. Toward the floor of the Great Valley below, the stratigraphic succession passes down through the Juniata and Martinsburg Formations and into Cambro-Ordovician carbonate units in the distance (Miller, 1961; Root, 1978).

This exposure demonstrates the relationship of the basal horizontally laminated lithofacies to the uppermost Juniata Formation upon which it rests. There is a small cove red interval at the top of the beach lithofacies, but in turn above the covered interval is a convincing example of the eastern cross-laminated (braided fluvial) lithofacies.

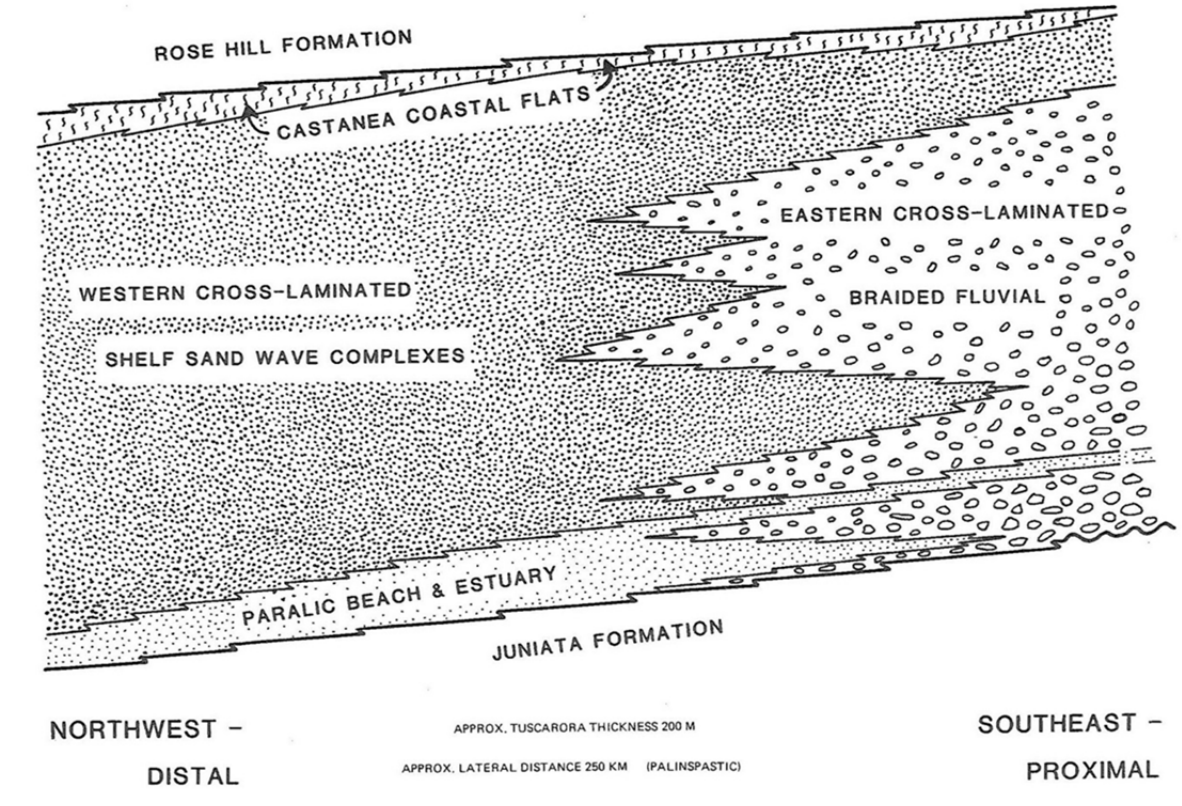


Figure 2. Generalized lithofacies profile in northwest – southeast transect of Tuscarora formation in central Pennsylvania outcrop belt.

Proximal locations, such as this and Stop 3, are significant in the context of reinterpretation of the Tuscarora. In the first place, the interpretation of beach origin for any part of the Tuscarora might be a contribution. But in addition, the demonstration of a lithofacies of beach origin at the base of the Tuscarora here at proximal localities shows that a significant transgressive event occurred as Tuscarora history began. The importance of this transgression will be reinforced at subsequent stops at which we view the base of the Tuscarora. This outcrop also demonstrates in a convincing way the role of depositional process in modifying the sandstone composition.

Blue Mountain, and the Tuscarora Formation that is its cause, can be traced eastward and northeastward to the Delaware Water Gap and on into New Jersey and New York. The basal horizontally laminated lithofacies has been traced for only part of that distance. Good exposures of the basal unit occur at Sterrett's Gap, at Susquehanna Gap (where it forms the Rockville Dam Member of Swartz, 1957; and Unit 22 of Dyson, 1967), and at Swatara Gap, about 40 km to the east. Outcrops east of there inadequately expose the base of the Tuscarora, but there are suggestions that the horizontally laminated lithofacies extends almost to the Schuylkill River, about 110 km east of this locality. Lateral correlation of the basal units of the Tuscarora is shown in Figure 12 and also on the composite lithofacies profile ***(Fig. 2).***

Juniata Formation

The maroon-red Juniata consists of interbedded composite units of sandstone and subordinate thin darker shales. The sandstone is medium- to coarse-grained litharenite, with poor sorting and subangularity ***(Fig. 25C)***. Most of the sandstone is cross-stratified, with troughs more abundant than planar types. Gravel sizes occur at the bases of some beds, and shale intraclasts are present. There is a poorly developed cyclicity of fining- and thinning-upward sequences. Note that the bases of a number of sandstone beds contain biogenic structures, some of which are organized into forms that suggest *Arthrophycus*.

These features indicate that deposition took place in braided river systems. This is not different from previous interpretations. What is important to note is the contrast with the features and origin of the basal 30 meters of the Tuscarora. However, in considering that striking contrast, do not overlook the similarity between features and origin of the uppermost Juniata and the features and origin of the eastern cross-laminated lithofacies above the covered interval over the beach lithofacies. These similarities include lithologic proportions sandstones composition and texture; interbedded shale and intraclasts of that shale; physical and biogenic structures, and cyclic vertical sequences.

I interpret this to mean that those uppermost Juniata river systems continued into Tuscarora time with the same magnitude and fluvial style. The only major change is in the color of the deposits. The basal transgressive event caused the deposition of a beach sequence along a retrograding coast, but there were times and places during which the river systems prograded out over the beach deposits. This is a pattern we shall examine at other stops (Stops 3, 6).

Basal Horizontally Laminated Lithofacies

In contrast with the units above and below, the basal 30 m of the Tuscarora here is all sandstone; there is no shale either interbedded or as intraclasts. Above a basal 2 m of coarser, poorly sorted sandstone, the unit is all fine to medium, well sorted, and has rounded grains ***(Fig. 25B)***. Grain size increases slightly at the top of the unit. All 30 m of this sandstone is quartz arenite; there are no lithic grains or chert.

The most common sedimentary structure is horizontal (even parallel) lamination. In thin section ***(Fig. 25B)*** this lamination is seen to consist of alternating laminae of coarser and finer grains. Some of the laminae show the reverse grading referred to as "beach lamination" by Clifton (1969). At about 15 m above the base, there is the broadly arching style of lamination known as antidune lamination on beach foreshores (Hayes and Kana, 1976) ***(Fig. 26A)***. Symmetrical ripples, although not photogenic, are present on exposed bedding planes ***(Fig. 26B)***. Other symmetrical ripples can be seen in cross section on the outcrop face (examine outcrop at about 14.5 m above base, near lower part of section illustrated in ***Figure 26A***. Cross-laminated beds are not common in this unit, and the two-dimensional nature of the outcrop surface makes it difficult to interpret those that do occur. I think that some of the cross laminae are inclined to the east or southeast; one of these occurs about 16 m above the unit base (near the painted black 14 on outcrop). Do you agree?

When one compares the 30 m of horizontally laminated sandstone with the underlying upper Juniata Formation and the overlying eastern cross-laminated lithofacies, there are some important features missing from this unit. There is no shale, either interbedded or as intraclasts. The average grain size of the sandstone is smaller, and there are no very coarse sand or gravel particles. Lithic grains and chert are missing from the sandstone. Cross lamination is almost absent, and the few examples show possibly anomalous transport direction. There are no apparent patterns of grain sizes or sedimentary structures. And there are no biogenic structures, such as *Arthrophycus.*

The characteristics of the basal horizontally laminated lithofacies consistently indicate that the environment of deposition was the lower foreshore and upper shoreface of a wave-dominated beach system.

Figure 25. Photomicrographs of sandstones at Waggoner's Gap; for each, the narrow dimension is 3.7 mm

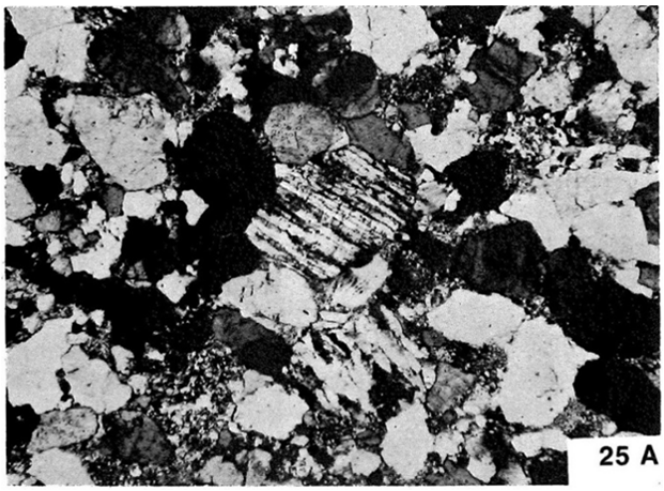


Figure 25A.
Upper Tuscarora unit; eastern cross-laminated lithofacies above covered zone

Figure 25B.
Basal horizontally laminated lithofacies about 15 m above Juniata contact. Shows inversely graded laminae. Pure quartz arenite.

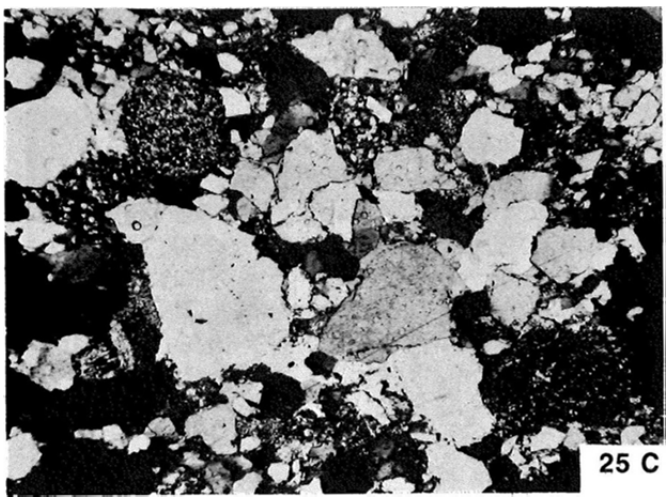


Figure 25C.
Juniata Formation about 3 m below contact with Tuscarora. Abundant chert and some rock fragments.

Eastern Cross-Laminated Lithofacies

Above the covered interval, the Tuscarora Formation has features that, but for color, are more like those of the uppermost Juniata than of the basal horizontally laminated lithofacies. Cross-laminated composite units of sandstone are interbedded with thin and lenticular beds of gray and greenish gray shale. The sandstone is medium to coarse grained, and contains granule and pebble lags at bed bases ***(Fig. 26C)***. Within the sandstone are shale intraclasts of the same composition as the thin shale interbeds. The sandstone is sublitharenitic, with fragments of sedimentary, metamorphic, and chert origins ***(Fig. 25A)***.

The most common sedimentary structure is trough cross lamination ***(Fig. 26D)***, generally ranging from 10 to 20 cm thick. Smaller scale current ripple lamination is uncommon, but present in finer-grained beds. The bases of a number of sandstone beds have preserved the biogenic structure *Arthrophycus*.

As reviewed in earlier parts of this guidebook and at Stop 1, the characteristics of this lithofacies indicate deposition in braided fluvial systems. As stated earlier, the similarity between this unit and the uppermost Juniata suggests that the magnitude and style of the river system was approximately the same for each unit, and that the transgression of the wave-dominated beach coast was temporarily reversed.

The compositional contrast of the horizontally laminated lithofacies with this cross-laminated lithofacies also illustrates the role of depositional processes in determining sandstone composition. If the quartz arenitic composition of the basal Tuscarora were due to the introduction of a changed source material to the depositional site, one should expect that the cross-stratified sandstone above the horizontally laminated sandstone would also be quartz arenite. However, there is a distinct compositional contrast between these two units, with the upper fluvial unit returning to the sublitharenitic composition characteristic of the uppermost Juniata, and also characteristic of the fluvial Tuscarora seen at Millerstown (Stop 1). Instead, composition of the sandstone is related to depositional environment. Fluvial sandstones are sublitharenitic to litharenitic (whether Juniata or Tuscarora) and the beach sandstone derived from that fluvial sandstone is quartz arenite.

Figure 26. Features at Waggoner's Gap. Scale is 15.2 cm long.

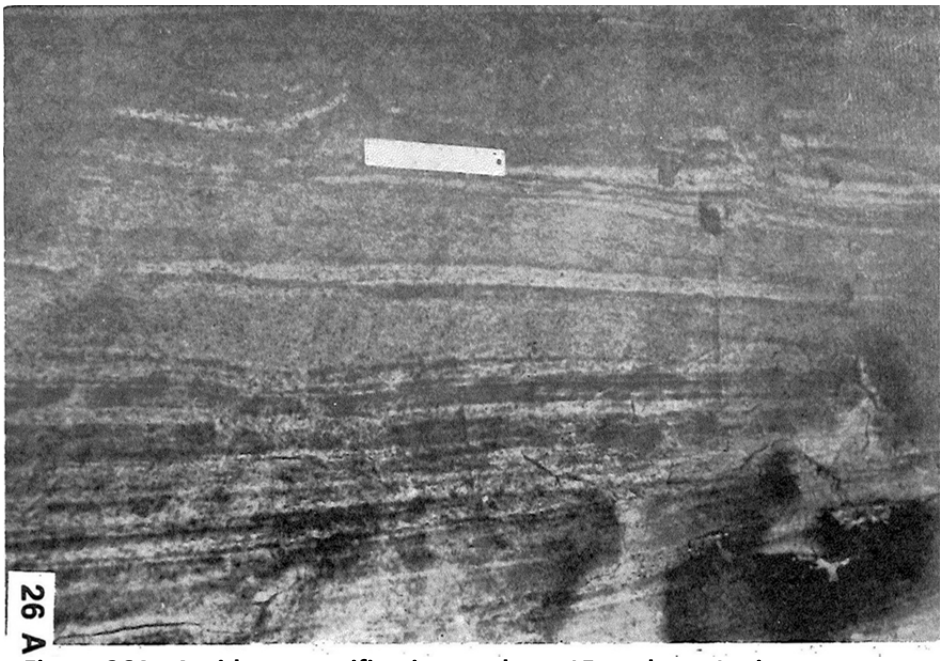


Figure 26A. Antidune stratification at about 15 m above Juniata contact.

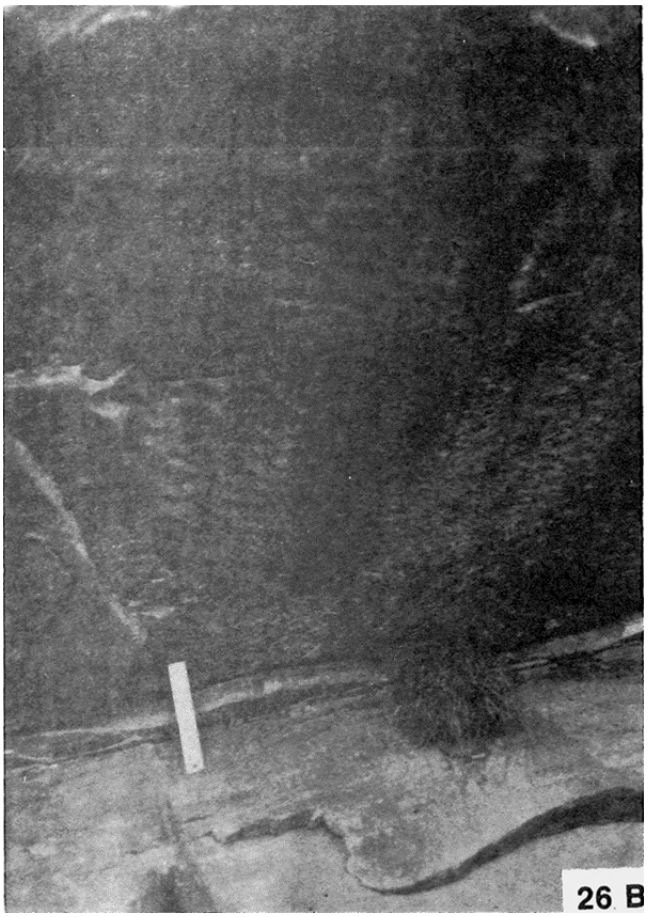


Figure 26B.

Symmetrical ripples on bed base; slightly above A.

Figure 26C. Basal lag gravel overlying shale bed; upper unit of eastern cross-laminated lithofacies.

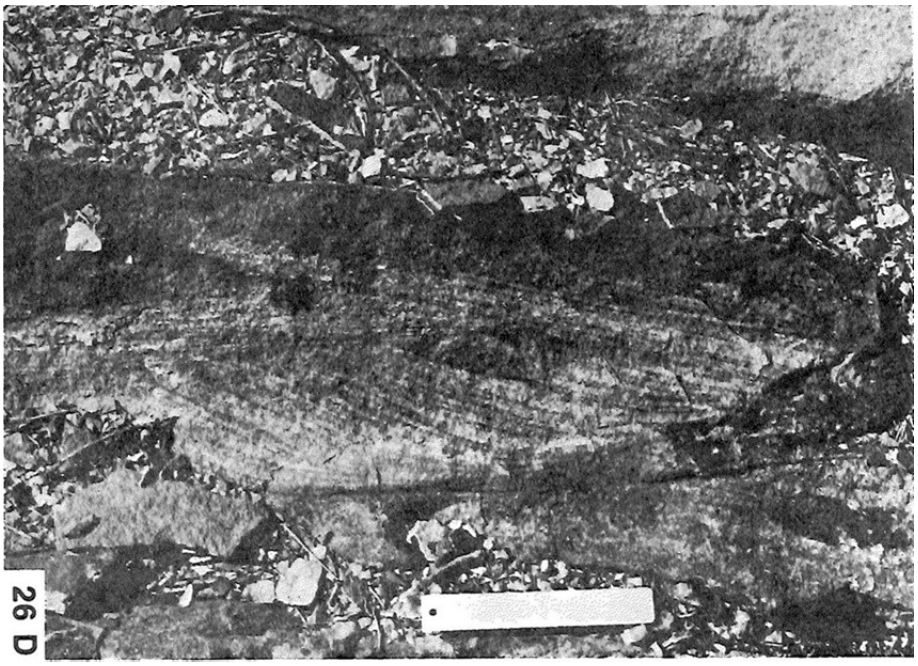


Figure 26D. Trough cross-laminated sandstone interbedded with shale; eastern cross-laminated unit above covered zone.

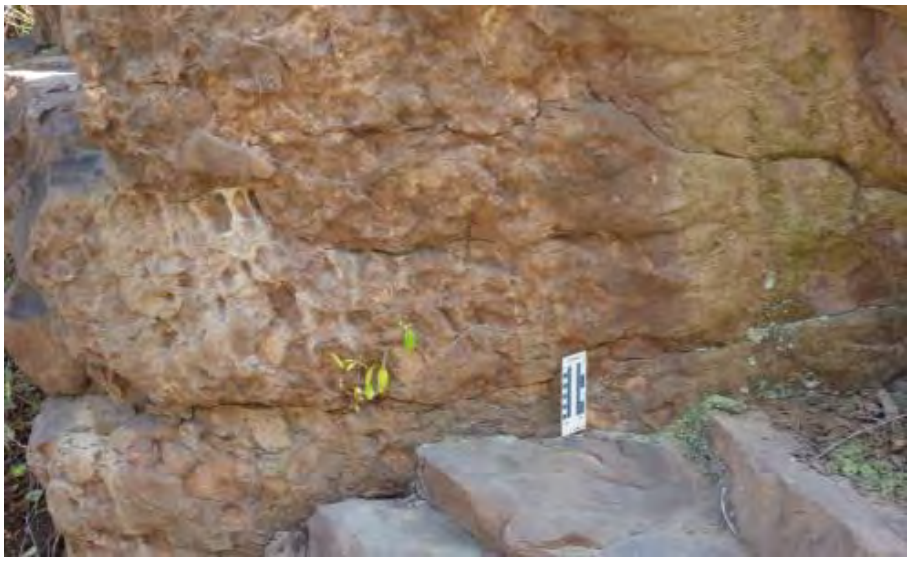
APPENDIX B.

Upper surface of a colluvium block of Tuscarora Formation sandstone at Waggoners Gap.

Depressed into the upper surface implies that the Arthrophycus burrowers were excavating into the underlying sandstone layer as well as the mud interlayer and overlying layer

Arthrophycus **burrows and "pimpled" relief features on the base of Juniata sandstone block at Waggoners Gap.**

Base of Juniata sandstone layer at Waggoners Gap with reddish mud lumps embedded into sandstone base.



Interval Mileage	Cumulative Mileage	= Stop Sign; = Traffic Light; "T" = T Intersection; TR = Township Route; "Y" = Y intersection
0.0	69.5	Drive south on PA Route 74
7.7	77.2	***Turn right*** onto College Street in Carlisle
0.5	77.7	***Turn left*** onto West High Street
0.4	78.1	***Turn right*** onto South Hanover Street
0.1	**78.2**	***ARRIVE*** **at Comfort Suites. END of 2014 FCOPG Field trip** **Comfort Suites, Carlisle PA**