THE CASE OF THE MISSING CATSKILL

clues from Wayne, Sullivan and Susquehanna Counties

WHERE

Tunkhannock PA

HEADQUARTERS: Shadowbrook Resort

WHEN

Friday & Saturday
October 4-5, 2019

FEATURING • Redbeds and the fining upward cycle • The Lockhaven and Catskill Contact • The "Haystack" Interval at Dutchman Falls • Paleosol • Steep Dips • Karst and Colluvium Waterfall & Landslide • Folding

84TH ANNUAL

Field Conference of Pennsylvania Geologists

TRIP LEADERS

Bill Kochanov
PA Geological Survey (ret)

Brett McLaurin
Bloomsburg University

PRE-CONFERENCE

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Thursday, October 3, 2019

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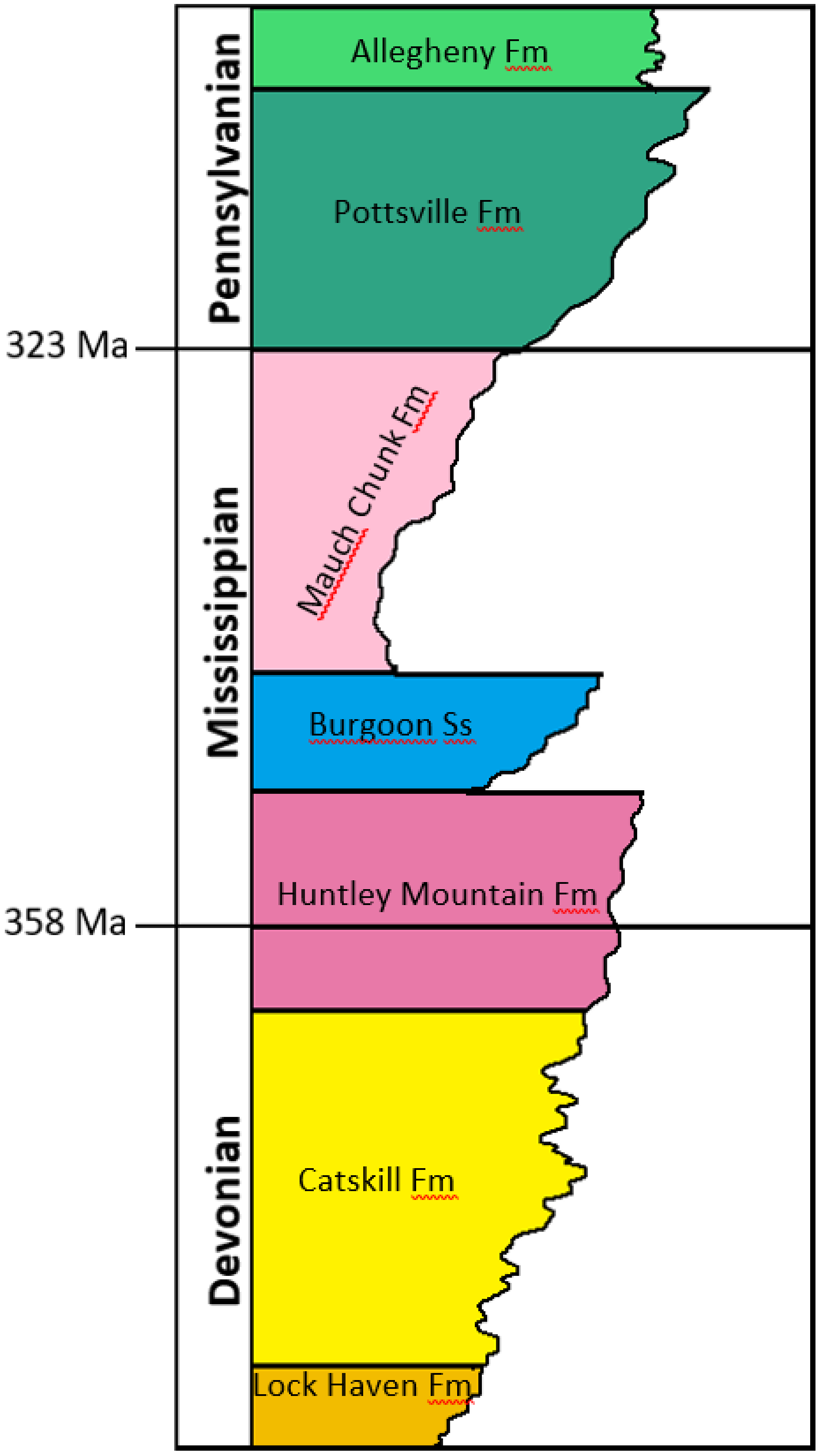

Lithology	**Depositional Environment**
Sandstone, siltstone, claystone, limestone, thick mined coals, plant and brackish marine fossils	Low-energy alluvial plain and lagoonal
Conglomeratic sandstone, including 40 to 70 feet of hard quartzite (Homewood) near the top; siltstone; coal; clay; plant and a few marine fossils	High-energy alluvial plain and lagoonal
Red-green, calcareous, clayey siltstone; fossiliferous limestone; crossbedded, 50-foot-thick, siliceous limestone (Loyalhanna) at base	Wet-dry to semi-arid alluvial plain to a shallow-marine sand complex
Fine to medium grained sandstone, rarely shale or clay, plant fossils	Braided stream to fluvial deltaic
Gray-red shale, olive gray sandstone	
Commonly green to red claystone, siltstone, and sandstone; fish bones and some brackish-marine fossils	Alluvial plane to marginal marine
Gray to green-brown sandstone, siltstone, and shale	

Road Log & Stop Description Guidebook for the

84th ANNUAL FIELD CONFERENCE OF PENNSYLVANIA GEOLOGISTS

October 4 — 5, 2019

THE CASE OF THE MISSING CATSKILL — Clues from Wayne, Sullivan and Susquehanna Counties

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Cover: Lock Haven to Catskill, marine to terrestrial transition, abandoned quarry, New Milford, PA
(*Photo of quarry by Craig Ebersole)*

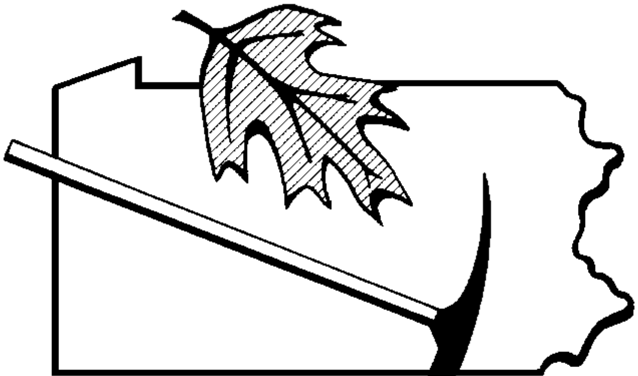


TABLE OF CONTENTS

Day 1 Field Trip – October 4, 2019

Day 2 Field Trip – October 5, 2019

Acknowledgements

This year's Field Conference would not be possible without the coordinated efforts of the Conference officers Kristen Hand, Steve Shank, Victoria Neboga, and Connie Cross. Overcoming many of the changes to the stop itinerary (four stops had to be replaced) and logistical issues (changing of the Conference headquarters from Carbondale to Tunkhannock) had all involved in quite a scramble. Special thanks also go out to Robin Anthony for helping to compile the guidebook. A nod also to Brian Dunst.

Acknowledgements also go to the Pennsylvania Geological Survey for initiating the Catskill mapping projects and sending Tom McElroy, Jon Inners, Rose-Anna Behr, Victoria Neboga, Greg Baluta, Mark Wildmann, Noel Potter the younger, and Bill K. into the wilds of Wayne and Susquehanna Counties. The U.S. Geological Survey is recognized for their financial support through the cooperative Statemap program.

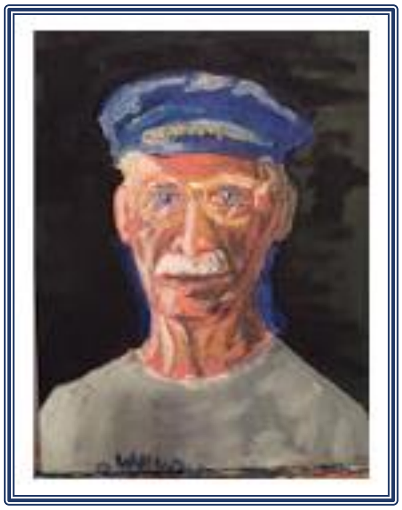
Tom Whitfield and Caron Pawlicki are recognized for their patience and technical guidance in translating our scrawled maps and data and turning them into works of art. Countless others for their comments and discussions, "Jim Bob" Shaulis, Cliff Dodge, Aaron Bierly, Rose-Anna Behr, Vik Skema, and Jon Inners; Craig Ebersole for his prowess in managing the Mavic-2-Zoom drone.

Thanks to Gale Blackmer, Stuart Reese, and Sim Suter, for providing opportunities to attend out service training and time in the field. Elizabeth Lyon for help running the administrative gauntlet. Steve Shank for geochem and thin section help; John Neubaum for help with the core; Sandip and Mark (Bhavesh too) for their indispensable guidance in computer lore and their patience with geologists; Ellen Fehrs for making the Conference road log "fun" and finally, to Jody Smale in the library for tracking down those hard to get references.

Bill Kochanov

In His Own Words

A few years ago, Don asked me to hold onto his obituary for him. He said I would know when to use it. Here is the man, the myth, the legend, in his own words:



OBITUARY – DONALD M. HOSKINS

Born May 22, 1930 in a smelly paper-mill town (Lyons Falls) in northern New York to a family of lumber and construction workers whose heritage were immigrants from England, France and Ireland. Graduating 3rd in a class of 6 in 1952 from Lyons Falls High School, where he first was introduced to earth science, he attended Union College, Schenectady, New York where, as an entering student, he declared his major as geology. Surviving the first semester, he was told by Dean C. William Huntley, "I see Mr. Hoskins that you have had a good time. I suggest, Mr. Hoskins, you have had your good time." Following this advice he graduated in 1952 and then matriculated at the University of Rochester after hearing from Dean Huntley that he would succeed in graduate school only if he was prepared to work. During the 1952 summer he was employed by Atlantic Richfield Company in Wyoming as a field assistant mapping potential oil prospects.

Graduating in 1954 from the University of Rochester with a Master's Degree he was drafted into military service serving most of his time as a topographic mapping specialist in Germany where he earned the Army of Occupation medal because he arrived there more than 30 days before the end of the occupation. While at Rochester, he met Barbara Ann Snyder. They were married September 2, 1953. Barbara joined him in Germany where they traveled AWOL widely on weekends experiencing much of the rural areas of Germany.

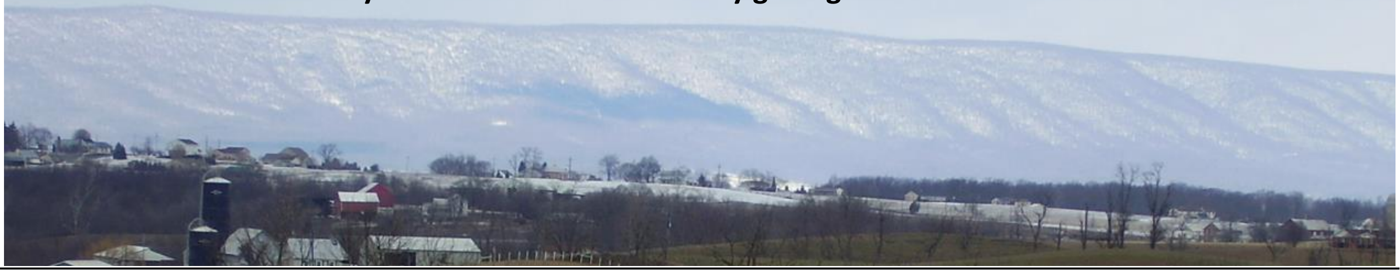
Returning to the United States in 1956 he was employed as a field geologist with the Pennsylvania Bureau of Topographic and Geologic Survey as a geologist specializing in mapping and paleontology. In 1958 he was provided an educational leave of absence to pursue a Ph. D. and graduated in 1960 from Bryn Mawr College where he was Coordination of Science Fellow between the geology and biology curricula.

Employed again in 1960 as a geologist with the Bureau of Topographic and Geologic Survey he became Chief, Geologic Mapping Division in 1962, Chief of Staff Services in 1963, and Assistant State Geologist in 1968. While Assistant State Geologist he pursued a Master of Government Administration degree from the Wharton School of the University of Pennsylvania, graduating in 1974. In 1986 he was appointed State Geologist. He retired in 2001 after more than 42 years of public service. While State Geologist he served as Secretary-Treasurer, Vice-president, President-elect and President of the Association of American State Geologists.

First attending in 1956, and becoming a member of the Unitarian Church of Harrisburg in 1963 he twice served on the Board of Directors and as Vice-president and President as well as being a member and chairperson of ministerial search committees as well as serving on many other committees. Most recently he has served on the Finance Committee and as Treasurer of the church. Singing as a member of Unisingers was one of his most favorite church activities.

He is survived by his spouse, Barbara, a remarkable musician who put up with all of his bad habits, daily inattentions because he would be rather thinking of geological maps or fossils, failures, and foibles; and three children, daughter Donna Michele Hoskins-Helm, (who was not named for him, although they have the same initials), son Steven Ralph Hoskins, and son Bruce Andre Hoskins, all of whom were accepted at one of the colleges from which he graduated, but none would think of going to any college where he had gone.

In lieu of flowers, contributions would be most welcome in support of the Unitarian Church of Harrisburg where, on most Sundays, he was present to share in the wisdom and fellowship and vision seen through its large windows. And when the Minister was boring he could look to the horizon to see Blue Mountain underlain by ancient rocks so favored by geologists.



In Memorium: Donald M. Hoskins, PA State Geologist from PA Environmental Digest Blog; Edited by David E. Hess; Friday December 7, 2018 http://paenvironmentdaily.blogspot.com/2018/12/in-memoriam-donald-m-hoskins-state.html

Donald M. Hoskins, who served as Pennsylvania State Geologist from January 8, 1987 until his retirement in January 27, 2001, passed away on December 5.

Don started with the Pennsylvania Survey in November 1956 and never left. Even after his retirement he was active in his life-long field of study continuing to lead geology tours, mentoring students and volunteering his time to help others understand a subject he loved.

“I remember Don as the consummate professional while he headed the Bureau of Topographic and Geologic Survey,” said DCNR Secretary Cindy Adams Dunn. “He continued his life of public service by assisting DCNR in mapping and by mentoring many current staff. He still has an office at the survey, and he will be missed by DCNR.”

“Don was a pro’s pro. He was extremely committed to the work of his Bureau. Don strongly believed in the value of his Bureau’s work to the health and welfare of Pennsylvania citizens,” said Richard G. Sprenkle, Deputy Secretary, DCNR (Retired). “For instance, topographic maps were important for bridge placement and construction, while geologic services were critical to watershed conservation efforts and mineral extraction.

“He was very supportive of his staff including efforts to find a more suitable headquarters as well as protecting them from adverse management and political threats,” add Sprenkle. “Don was a true and unselfish advocate for his successor, Dr. Jay Parrish, at his retirement. He was also quite the accomplished sailor. I have lost a good friend and will treasure what he taught me about the natural and geologic resources of this great Commonwealth.”

The following tribute to Don appeared in Pennsylvania Geology, the magazine published by the Survey, and was written by his long-time colleague Thomas M. Berg on Don's retirement from the Survey in 2001—

In this issue of Pennsylvania Geology, I am honored to pay tribute to fellow State Geologist Donald M. Hoskins, who has served the Commonwealth of Pennsylvania as Director of the Bureau of Topographic and Geologic Survey since January 8, 1987, and who is retiring January 27, 2001.

During his 14 years as State Geologist, the Pennsylvania Survey has achieved great things. I was not at the Survey to observe all of them firsthand, but I did witness great accomplishments under Don's leadership during the years I spent there, from 1965 to 1989.

During most of those 24 years, I was influenced by Don's management and geological career together with the direction of former State Geologist Arthur A. Socolow. I learned much from both Art and Don that has been invaluable to me as Chief of the Ohio Geological Survey.

Don came to the Pennsylvania Survey in November 1956 and shortly thereafter obtained his doctorate in geology from Bryn Mawr College. He conducted detailed geologic mapping in the Ridge and Valley province and authored the outstanding Fossil Collecting in Pennsylvania (General Geology Report 40).

I got my first impression of Don Hoskins when I came to interview for a field mapping position with the Bureau in late 1964. Don was asked to ferry me around Harrisburg to show me some housing possibilities for my family.

I handed over the keys to my Dad's car and got the high-speed tour. He didn't waste a moment. Don was obviously someone who got things done quickly, but I was glad to get the keys back. We hit it off right away because we were both very interested in paleontology. He still maintains that interest, as I do.

Those first impressions of Don were amplified shortly after I began work at the Pennsylvania Survey when he led a staff field trip to his mapping area north of Harrisburg. A convoy of state cars full of excited geologists zoomed through the valleys and along the ridge crests.

After examining outcrops at the nose of one ridge, we discovered that someone had closed and locked the road gate; most of the Survey was trapped in the middle of nowhere. I naively thought someone would have to walk out and find a key.

However, with two swift blows of his rock hammer, Don dispensed with the lock and we were on our way. Small things never got in Don's way.

Few years passed before Don Hoskins moved into the position of Editor, and then Assistant State Geologist. No one could ever accuse him of lacking ambition.

I knew him as Assistant Director for most of the years I was with the Pennsylvania Survey. Don confronted state-government bureaucracy head-on. He even went to the trouble of attending night school to obtain a master's degree in government administration.

With the very best of them, Don could handle annual budgets, Theory-X management, government audits, decision trees, Gantt charts, position descriptions, personnel-evaluation systems, goal-and-objective setting, PERT networks, management by objectives, strategic planning, and all the trendy management schemes that government bureaucrats continually unearth.

To his great credit, Don recognized the urgent need to market the Survey and all of its services.

I greatly enjoyed joining Don in giving presentations about the Survey to county officials, trade organizations, other state agencies, and university geology departments.

In his own way, he always maintained the strong applied-science and public-service focus that Art Socolow had cultivated for the Pennsylvania Survey.

Now don't get me wrong. Don Hoskins never succumbed to management superciliousness. Although he embraced the management world with a vengeance, he always remained a first-rate geologist. He kept up with the science.

For decades, Don worked hard to maintain and promote the Field Conference of Pennsylvania Geologists. A lot of good science was (and still is) accomplished through the Conference.

You could always count on hearing a geological presentation by Hoskins at regional and national Geological Society of America meetings. (Don is a GSA Fellow.) All aspects of geology fascinated him.

At a meeting in Providence, R. I., as Don, Bill Sevon, and I were walking to our hotel after dinner, we became captivated with the green-stone base course of a building. Picture the scene: three well-dressed gentlemen on their hands and knees on the sidewalk with noses and hand lenses pressed up against the stone. That's dedication!

As I knew him, Don Hoskins was also more than the consummate scientist and geological-survey manager. I remember many of his other outside interests.

Don grew roses, cultivating unusual varieties. He made fine wines. He became an outstanding sailor, plying the waters of Chesapeake Bay-- always wearing his Greek fisherman's hat.

Don was constantly interested in physical fitness. He was dedicated to maintaining good health by following the Royal Canadian Air Force daily fitness routine.

I will never forget sharing a motel room in Troy, N. Y., with Don and four other geologists (saving money on a tight travel budget). At about 5:00 a.m., a fearful and persistent stomping noise accompanied by heavy breathing awakened me in the darkened room. It was Don running in place as he did his fitness routine.

With all of his outside interests, Don knew how to celebrate life. He and his wife Barb were always deeply devoted to their children and their careers. His sense of history and his fascination with the history of geology were contagious.

To know Don is to become immersed in the growth and development of our science.

As State Geologist of Pennsylvania, Don Hoskins has worked hard to maintain the Bureau of Topographic and Geologic Survey. Like so many other state geologists, he has had to struggle with the "cut government spending" wave that continues to prevail.

Politicians and government bureaucrats persistently overlook the long-term value of geological surveys and the work that they do. Yet Don has never given up the ghost.

He has endeavored to market the Pennsylvania Survey and make the geological sciences serve the public good. He has been faithful to neighboring state geologists and the Association of American State Geologists (AASG), serving as president of that association.

Don has maintained influential and constructive relationships with the U.S. Geological Survey (USGS) over the years, participating in many cooperative projects with the national survey. Through several AASG committees, he has worked hard to help the USGS keep its focus on citizen needs.

Pennsylvanians have been well served by Dr. Donald M. Hoskins, State Geologist and Director of the Bureau of Topographic and Geologic Survey. Like his predecessors, he has left a legacy that will sustain his successors.

The times are changing. The state geological surveys face new challenges in the information-technology revolution. But I believe the Hoskins legacy leaves the Pennsylvania Survey on solid ground.

Many thanks to you, Don. I wish many happy years to you as you embrace new challenges ahead.

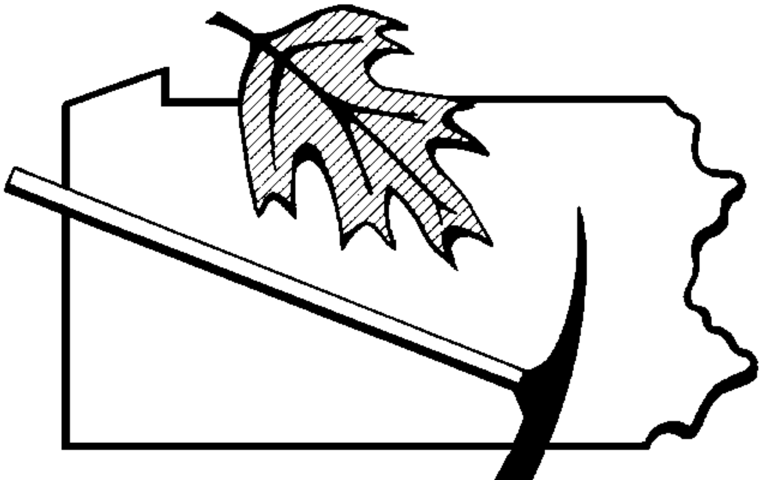
Go to http://docs.dcnr.pa.gov/cs/groups/public/documents/document/DCNR_006826.pdf to see the full article and related photos of Don through his career at the Survey.

For more information on the Survey today, built on a foundation of the first Pennsylvania Geologic Survey in 1836, visit DCNR's Bureau of Geological Survey (Also known as the Pennsylvania Geological Survey) webpage.

Privileged to have called him my mapping partner, my mentor, my friend.

He will be forever missed.

Kristen



THE CASE OF THE MISSING CATSKILL — Clues from Wayne, Sullivan and Susquehanna Counties
84th Annual Field Conference of Pennsylvania Geologists

Introduction

This year's Field Conference focuses on the great orange block (Figure 1) of the present geologic map of Pennsylvania (Berg and others, 1980; Miles and Whitfield, 2001); northeastern Pennsylvania's, the Catskill Formation, undivided. Unfortunately, some of the stops we initially selected became unavailable and other sites had to be substituted. We are sorry because they really were good sites. As reparation, we have decided to list these initial sites and provide some basic information so that individuals or small groups could visit them at some time in the future. Coordinates (and contacts if applicable) will be added to a brief description in the Appendix at the back of this guidebook.

Much of this year's adventure is derived from bedrock and surficial mapping projects over the past two decades (Figure 2), which is a closeup of the area outlined in the black square in Figure 1. Relatively recent mapping projects were designed to regionally characterize the Catskill Formation and determine if separate mappable members could be defined within it.

Nearly all of the Upper Devonian rocks in Wayne and Susquehanna Counties of northeastern Pennsylvania (Figure 3) are mapped as undifferentiated Catskill Formation and are interpreted to be part of a fluvial-deltaic system and sub-systems characterized by repetitive sequences of olive-gray to greenish gray sandstone (mix of braided and meandering channel sands, levee sands), siltstone, shale, and mudstones (levee and overbank sediments) and rare small-pebble conglomerate and calcareous intraformational conglomerate or agglomerate (channel lag and overbank sediments). "Redbeds" defined as variants of brownish-gray to reddish-gray hues, were primarily limited in occurrence, regulated to flagstone quarries and small aggregate pits.

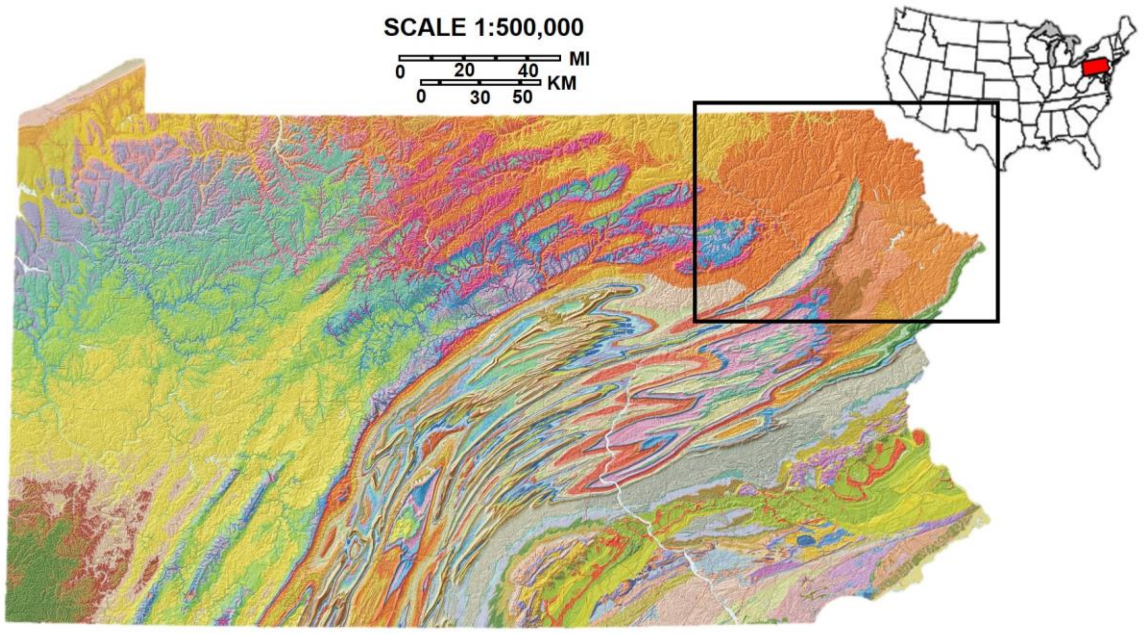


Figure 1. Geologic map of PA showing the location of the "orange block" of the Catskill Formation, undivided, covered in this year's Field Conference.

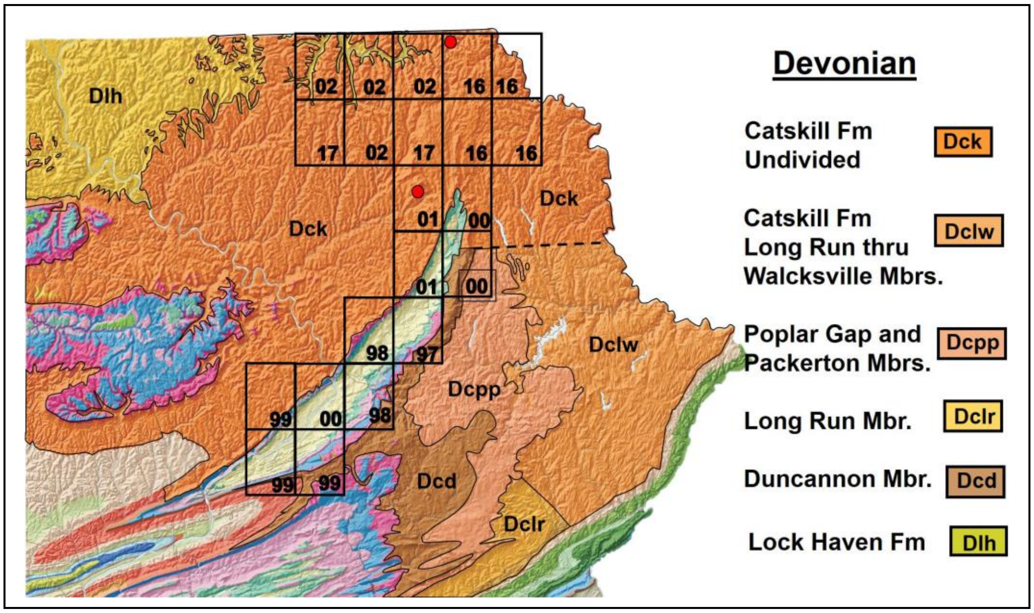


Figure 2. Geologic map of northeastern Pa showing 7.5-minute quadrangle boundaries and the year each quad was mapped. Red dots indicate cored boreholes.

The topographic settings ranges from the steep-sloped terrain to rolling plateau uplands. Vegetative cover, land disturbed by farming, glacial, colluvial and alluvial cover, provided some obstacles in locating outcrop exposures. Seemingly good outcrops were largely detached and rotated from their original position, thanks largely in part to the Pleistocene, limiting the reliability of bedding orientation. Interpreting field descriptions from past workers also posed additional difficulties due to oftentimes generalized outcrop locations and outdated landmarks.

Lateral and vertical stratigraphic control is quite often compromised by the lack of contiguous outcrops or extensive bedrock sections. In a cumulative sense, what was in situ provided adequate detail for the compilation of an idealized fining upward sequence (Figure 3) that served as a basis for interpretations across the bi-county area.

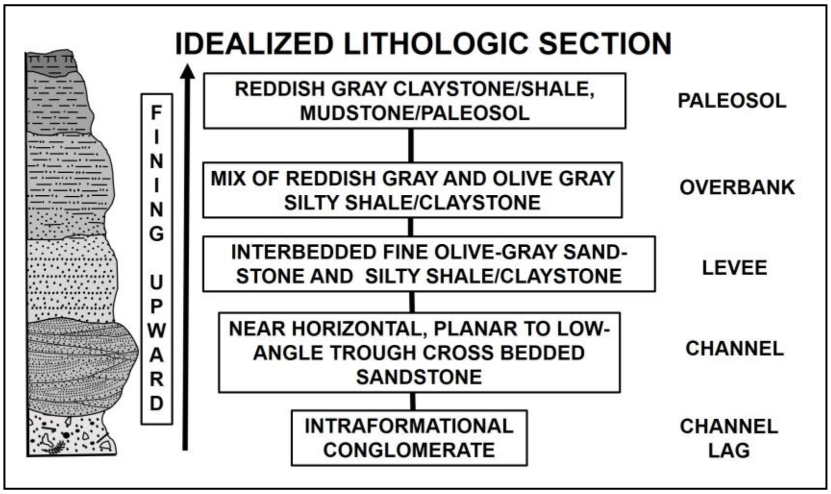


Figure 3. Idealized fining upward section.

This ideal sequence begins with a calcareous intraformational conglomerate aka “agglomeratic” beds whose sediment was derived from an erosional event. These events are interpreted to be similar to flash floods where the Devonian upland surfaces of soils, fluvial terraces, weathered outcrops, were washed of loose rocks, pedogenic clasts, saprolite, and vegetation, and then transported and deposited as lags within the stream channels or were deposited over the levees and out onto the lows of the Catskill fluvial plain. As the flooding waned, the different sized sediments sorted accordingly, recording the ebb and flow of the event as beds, laminae, and a variety of sedimentary structures (Stops 1, 7, and 10).

The erosional agglomerates mark the onset of the cycle, followed by, and sometimes incorporated with, coarser sandstones grading upwards into finer-grained, more planar and laminar sandstones. Many of the sandstones observed in hidden outcrops in the woods (Supplemental site 1) are generally stacked beds of near horizontal and low-angle trough cross bedded sandstones averaging 1-2 meters thick. The rather moderate thicknesses inferring a relatively shallow and somewhat broad channel fluvial system. These stacked exposures appear to fall into the category of braided streams but may also be evolved segments of meandering streams with sand and point bars shifting along the banks and within the active channel. The laterally accreting floodplains become somewhat easier to envision within a low elevation, topographical setting. The generally occurring medium-grained sandstones being reflective of being somewhat more removed from the influence of Acadian tectonic activity and being more influenced by climatic variables, i.e. dry and wet seasons and physical attributes such as the size of the drainage systems. It would not be farfetched to imagine various sized drainage basins covering large expanses of alluvial and upper delta plain regimes. What would be encountered over Susquehanna and Wayne Counties may be a function of multiple drainage basins. Its rock record being dependent upon the which tributary one encounters on the way to the Devonian seaway.

The levee and overbank sediments would be open to secondary or even tertiary flood basins separate yet connected to a complex river system. Modern-day examples of such complex systems, such as the Betsiboka River in Madagascar (Figure 4), can provide insight into the possible workings of the Upper Devonian Catskill environment.

Figure 4. Betsiboka River delta, Madagascar. Note the discharge of reddish brown sediment-laden water into the Mozambique Channel (i.e., Indian Ocean). Nasa photo ISS005-E-9416
https://city.jsc.nasa.gov/SearchPhotos/photo.pl?mission=ISS005&roll=E&frame=9416

What of the paleosols? It may have been that the cyclicity of wet and dry climatic periods afforded sufficient segregation of the fluvial landscapes and provided the stability (time), in part, to allow the development of soil or partial soil development. In the final throes of the fining upward cycle, the lithic sequence grades into greenish gray silty shales containing scattered plant fossil fragments and debris. This being followed by greenish gray silty claystone mixing with brownish gray to reddish gray claystone, culminating with a partial or well developed brownish to grayish red paleosol.

Tops and Bottoms

In selected areas of Susquehanna and Wayne Counties, the Catskill exhibits the transition to a marine setting (e.g., Stop 7). The admixing of sediments in suspension, the chemical changes from fresh to saline water, the dispersal of sediments by tides and currents, all add to a myriad of possible facies types encountered in the rock record.

Over these two counties the case for a "marine member" falls upon the argument of first redbeds or last of the marine fossils. Since the first attempts to identify the bottom contact came the ubiquitous conclusion that the bottom contact is gradational with the Lock Haven. It became a common fact that evidence for a marine fauna, either invertebrate or trace fossils came within the 30 to 60-meter zone north or south of the Catskill/Lock Haven border. It also became apparent that the lower contact pays little heed to the presence of redbeds.

Redbeds have been observed within the Lock Haven at other locations. One example comes from the 2013 Field Conference, Stop 8, Figure 8-2 (reprinted as Figure 5, left, below). At Stop 9 the brachiopod *Lingula* was collected within one of the redbeds denoting a restricted or possibly brackish environment (Figure 5, right, below). It is not surprising as one can imagine a flush of red sediments tied into periodic discharges from the Catskill drainage systems. Such influxes of sediment and fresh water would have unfavorable impact on more stenohaline and filter feeding organisms who would not be able to adapt to such abrupt environmental changes. Those more eurytopic organisms, such as *Lingula*, would be more flexible with regard to those changes. The bottom line, at least for Susquehanna and Wayne Counties, is that the presence of redbeds is but one criterium for use as a lower contact break. The use of fossils becomes a second. It does not answer all the questions, but it is a start.

Figure 5. Redbeds (arrows)within the Lock Haven (greenish gray beds); right, section of redbeds with chaotic arrangement of marine brachiopods.

With regard to the upper contact of the Catskill, the Spechty Kopf Formation, the stratigraphic unit overlying the Catskill, does not make it into northeastern PA where Sevon and Woodrow (1985) suggest in their regional stratigraphic cross section (p. 4) that it and part of the upper Catskill (Duncannon Member) had been removed through erosion. This is supported by its absence halfway up the "big banana" (Northern Anthracite Field) as well as its absence on Elk Mountain and Mount Ararat (Stop 12). The Huntley Mountain Formation (Spechty Kopf equivalent) is discussed further at Stop 4.

Stratigraphy

Rogers (1858) called it the “table land.” White (1881) characterized Wayne and Susquehanna Counties as “… an almost horizontal inclined plane, of Catskill measures…” estimating that 95 percent of the rock is Catskill. These early descriptions became the norm as the paucity of outcrop and relatively horizontal bedding contributed to the lack of detailed stratigraphy for the Catskill in this section of Pennsylvania.

White (1883) described a number of key beds or sections during his tenure to serve as reference points for correlations across the two-county area (Figure 6). One of the problems encountered by recent investigators was the differentiation of similar lithologies, particularly the sandstones, from one location to the next.

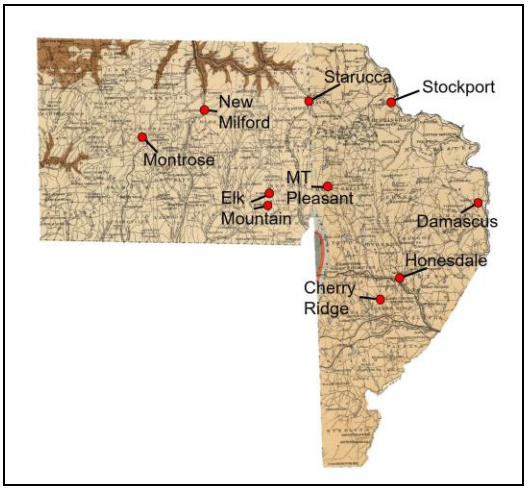


Figure 6. Second Geological Survey map showing the location of White’s (1881) localities for key beds and sections within the Catskill.

Since Rogers and White, bedrock mapping has been handed down “as is” to subsequent generations of geologists, displayed as “Catskill, undivided” on the series of state geologic maps down to the present version (Berg and others, 1980; Whitfield and Miles, 2001). However, there were periodic advances in characterization of the Catskill fluvial-deltaic system.

Willard (1936, 1939) used the subdivisions of White (1881) in constructing a mappable framework for the Catskill. He did, however, recognize that some of White’s subdivisions were too local in extent to be of value in a regional sense.

A symposium on Middle and Upper Devonian stratigraphy gathered researchers from Pennsylvania and surrounding states in an attempt to place the current understanding of the Catskill into perspective (Shepps, 1963). Although instructive, barriers remained between lithostratigraphic and chronostratigraphic approaches to defining units within the Catskill.

Glaeser (1963) examined bedrock exposures in the Lehigh Gap of Carbon County, two counties south of the study area, constructing a reference section for the Catskill which comprised all the rock between the Mississippian Pocono Formation and Devonian Trimmers Rock Formation. He presented arguments essentially dismissing the major units identified by both White and Willard as lacking lateral continuity and mapability at a 1:24,000 scale, and that their type localities were incomplete. The fifteen distinct units Glaeser identified did not improve the situation regarding nomenclature – his units ranged from “A” to “O” – but they did provide a type section of sorts to serve as a basis for future mapping, at least within proximity of the Lehigh Catskill “type section.” Detailed bedrock mapping in Monroe and Pike Counties by Epstein and others (1974), Sevon (1975), Sevon and Berg (1978), and Sevon and others (1989) used the “type” Glaeser section as a base for the Catskill, fitting the sections they observed into established and newly established stratigraphic units. Unfortunately, their efforts did not extend northward beyond the Wayne/Pike County line.

Figure 7 shows acceptance and changes of stratigraphic subdivisions and nomenclature over time. Note that the column of Epstein and others (1974) and Glaeser (1963) represents units in the Lehighton and Palmerton quadrangles in Carbon and Northampton Counties and may not be transferrable to Wayne and Susquehanna.

Rogers (1858)	White (1882)	Willard and others (1939)	Fletcher and Woodrow (unpublished 1970, 1972)	Epstein and others (1974); Glaeser (1963)	McElroy and Inners (2002)
Vespertine Series (X)	Pocono Series (IX)	Pocono Formation		Pocono Formation	Pocono Formation
	Mt. Pleasant Cong.			Duncannon Member	
	Mt. Pleasant red shale		Mt Pleasant Formation		
				Clark's Ferry Member	
	Elk Mountain Sandstone and shale				Lanesboro Member
				Berry Run Member	
Ponent Series (IX)	Cherry Ridge Group	Cherry Ridge red beds	Cherry Ridge red beds		
	Honesdale sandstone	Honesdale sandstone	Honesdale sandstone	Sawmill Run Member	
	Montrose red shale			Packerton Member	
					Great Bend Member
	New Milford red shale	Damascus red shale	Stockport Formation	Long Run Member	
Vergent Series (VIII) (shales)	Chemung Formation	Undifferentiated marine	Walton Group	Beaver Dam Run Member	Lock Haven Formation
				Walcksville Member	
				Towamensing Member	

Figure 7. Stratigraphic subdivisions for the Pocono, Catskill, and Lock Haven Formations by different investigators.

More recent bedrock mapping by Inners (2002) and McElroy (2002) subdivided the Catskill in the Great Bend and Susquehanna 7.5-minute quadrangles of Susquehanna County into a lower “Great Bend” Member and an upper “Lanesboro Member”. The apparent difference between these two “members” however, is the presence of marine invertebrate fossils within the “Great Bend Member” at several horizons (Inners, 2004).

The Stockport Formation (basal Catskill) was proposed by Woodrow and Fletcher (1972, unpublished) for a series of exposures along Stockport Road (T-605), Hancock quadrangle (Wayne County), ranging in elevation from ~ 900 to 1500 feet. Rogers (1858) mentions the section at Stockport with “…Thin seams of a dark-coloured slate” sometimes appearing between the strata (sandstone), presenting “…long, level beds of the thinly splitting sandstone…alternating with red shales and sandstones…” The upper and lower boundaries of the Stockport were marked as “dark-gray shales” (Woodrow and Fletcher, 2002) and stated as equivalent to units in New York state (Corning Member of the Gardeau Formation). No invertebrate fossils were observed.

The relationship of “dark-gray shales” as mentioned by Woodrow and Fletcher (2002) is rather ambiguous as its use is from the Upper Devonian of Bradford County. The point being that there are sporadic gray shales at various intervals eastward through Susquehanna and Wayne Counties. The discontinuous nature of these units does not support their interpretation as a regional marker bed. Additionally, the dark gray coloration, fissility and presence of marine invertebrate fossils has not been observed in the Starrucca 15-minute quad. It is not unreasonable to conclude that equivalent strata along that timeline may indeed be present, but it appears more likely that such organic–rich shales did not extend much beyond western Susquehanna County.

Lithologic variations from upper to lower deltaic environments interpreted for the Catskill, make it somewhat difficult to place one shale unit in a correlative position with another without some sort of guidance, either geochemical, geophysical, or paleontological. In 2016, Kochanov examined the Stockport section and failed to find the dark-gray shales. Be as it may, one person's dark gray is another's greenish gray. Color characterization among the gray hues turns out to be an important field issue as anyone knows from describing core beneath a blue colored canopy.

The Elk Mountain and State Game Lands No. 170 boreholes, plus field surveys, provide a near complete representation of the Catskill section for Susquehanna and Wayne Counties. Using the Elk Mountain borehole as a guide one could split it into three sections (Figure 8) and express that as a stratigraphic column (Figure 9).

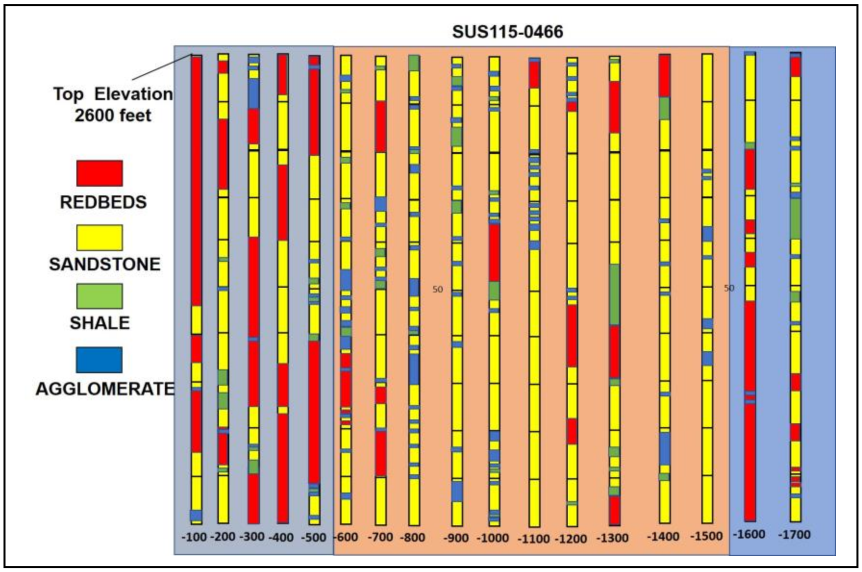


Figure 8. One possible interpretation of lithologic splitting of the Elk Mountain borehole.

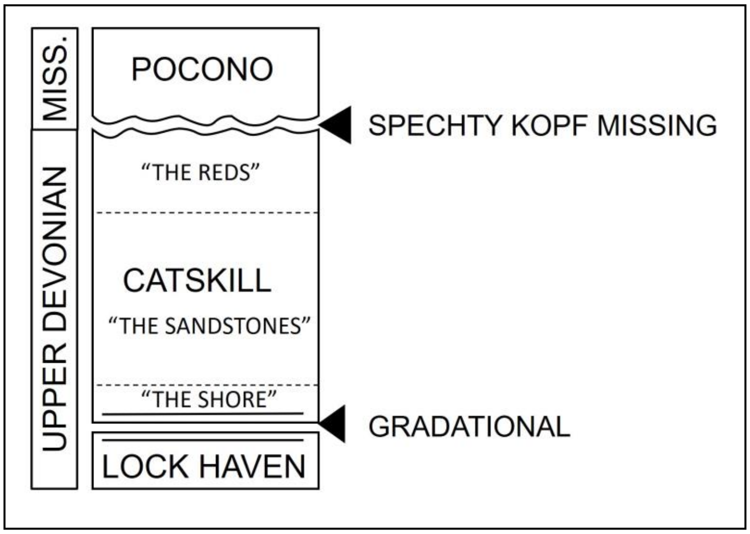


Figure 9. Stratigraphic column based on the Elk Mountain borehole where "the reds" represent the top 500 feet, "the sandstones" as the predominantly sandstone section 500 to 1500 feet, and "the shore" as the transition to the marine Lock Haven 1500 to 1700 + feet.

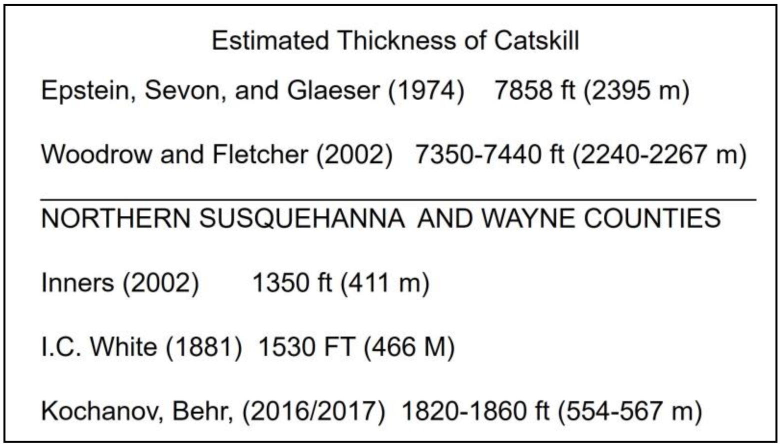
The trend suggests three sections but at what bed would one use as the separator, as the section, in all likelihood, is gradational from one lithofacies to the next?

Estimated Thickness of the Catskill

The thickness of the Catskill in Susquehanna and Wayne Counties is based on the two boreholes WAY 127-0426 and SUS 115-0466. The 1000-foot Wayne County borehole, at a surface elevation of 1886 feet, provided 960 feet of Catskill; the top of the marine Lock Haven was picked at -960 feet. The surface elevation for the 1704-foot Elk Mountain borehole, drilled on the south knob, was 2604 feet. Marine fossils were not observed but it was estimated that the top of the Lock Haven was at approximately -1750 feet (+- 20 feet). Catskill strata is present atop the north knob of Elk (Stop 12) at an elevation of 2693 adding an additional 89 feet of Catskill thickness. An estimated range of thicknesses for the Catskill in Susquehanna and Wayne Counties is 1819 to 1859 feet (Figure 10). Note in Figure 10 the expanded thicknesses for the areas outside of Susquehanna and Wayne Counties.

I.C. White (1881, p. 71) estimated the thickness of the Catskill at approximately 1530’ based upon the addition of the thickness of his subdivisions. However, it should be noted that the upper subdivisions were measured in southeastern Susquehanna and middle Wayne Counties and the lower subdivisions measured in middle and northern Susquehanna County. Furthermore, he added that the upper subdivisions for northern Susquehanna County have been removed. This removal of the upper subdivision (see top 500 feet of the Elk Mountain borehole Stop 12, Figure 12.6) jives with the lack of redbeds observed over the Susquehanna/Wayne plateau surface (Stop 12, Figure 12.2). To be fair, he did not have the Elk Mountain borehole to refer to, but his observation of the “removed” Catskill gave him a relatively close estimated thickness of the Catskill for the two-county area.

Based on the missing Spechty Kopf Formation atop Elk Mountain and Mount Ararat, where the Catskill is in contact with the overlying Pocono Formation (Stop 12 suggests that the Catskill may have been thicker).



Estimated Thickness of Catskill

Epstein, Sevon, and Glaeser (1974) 7858 ft (2395 m)

Woodrow and Fletcher (2002) 7350-7440 ft (2240-2267 m)

NORTHERN SUSQUEHANNA AND WAYNE COUNTIES

Inners (2002) 1350 ft (411 m)

I.C. White (1881) 1530 FT (466 M)

Kochanov, Behr, (2016/2017) 1820-1860 ft (554-567 m)

Figure 10. Estimated thickness of the Catskill from various investigators. Note the changes in estimates for Susquehanna and Wayne Counties.

Structure

The relative flatness of the physiographic plateau reflects the low angle bedding dips of the underlying sandstones and their weathering along the predominantly north-south east-west jointing pattern throughout northeastern Pennsylvania (Stops 10 and 11). Folding and faulting is generally absent from bedrock exposures in Wayne and Susquehanna Counties. Slickensided bedding surfaces were observed at one locality in the Lake Como area, Wayne County, approximately parallel to bedding, trending to the north. This may infer some related movement tied into the formation of the Northern Anthracite Field (Eggleston and others, 1992; Harrison and others, 2004). Folded bedding is best viewed in the Sullivan County Stops 2 and 5.

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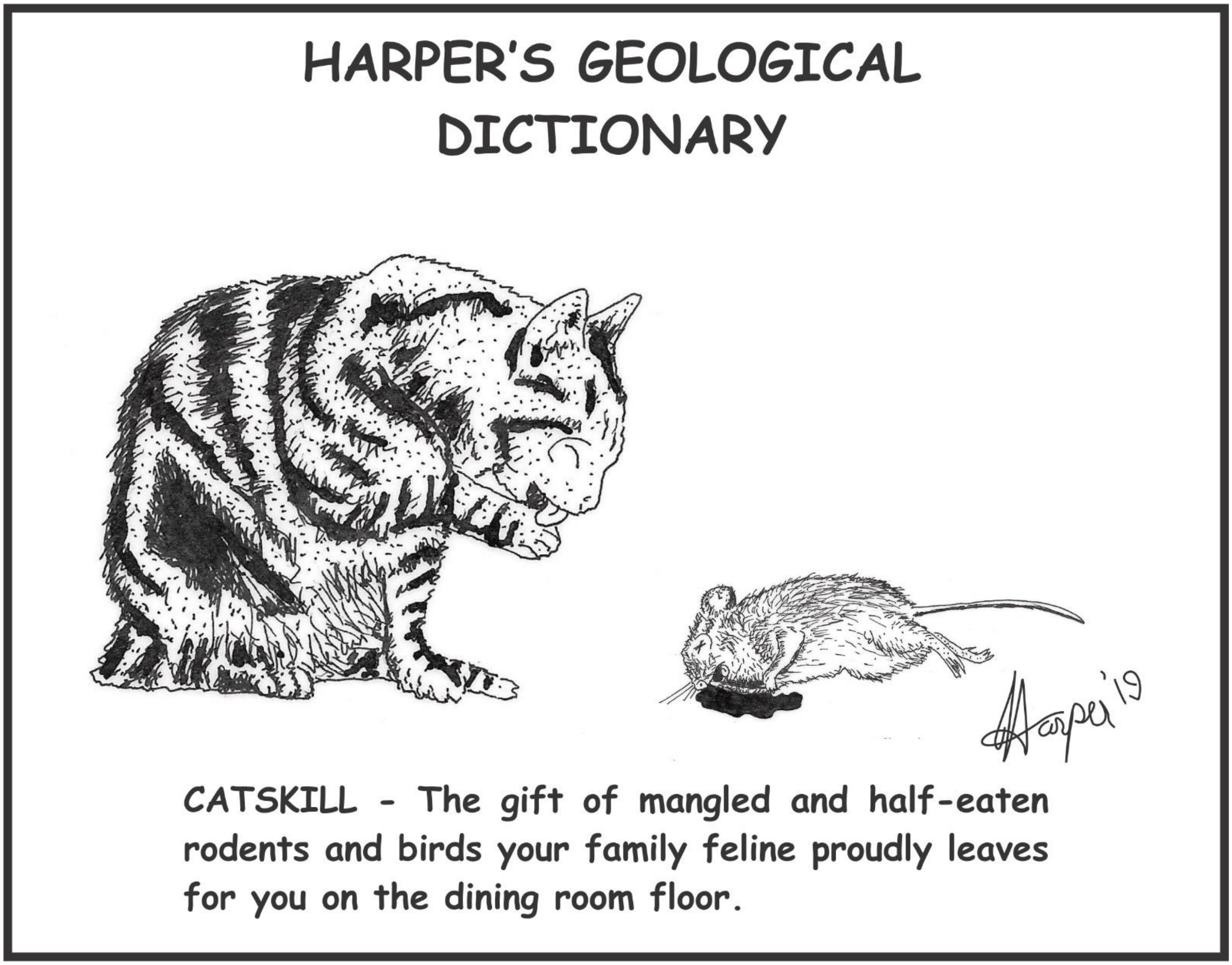
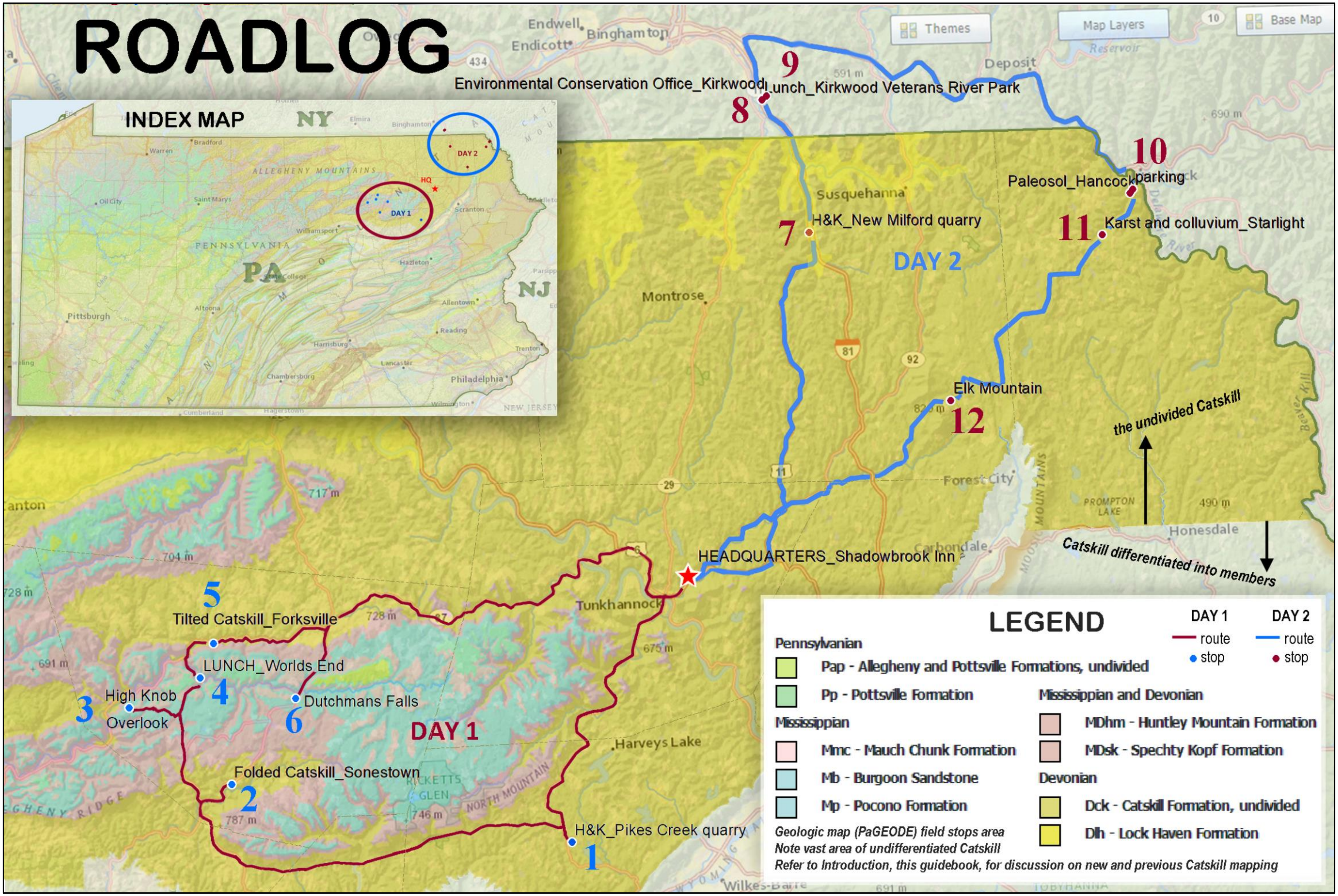
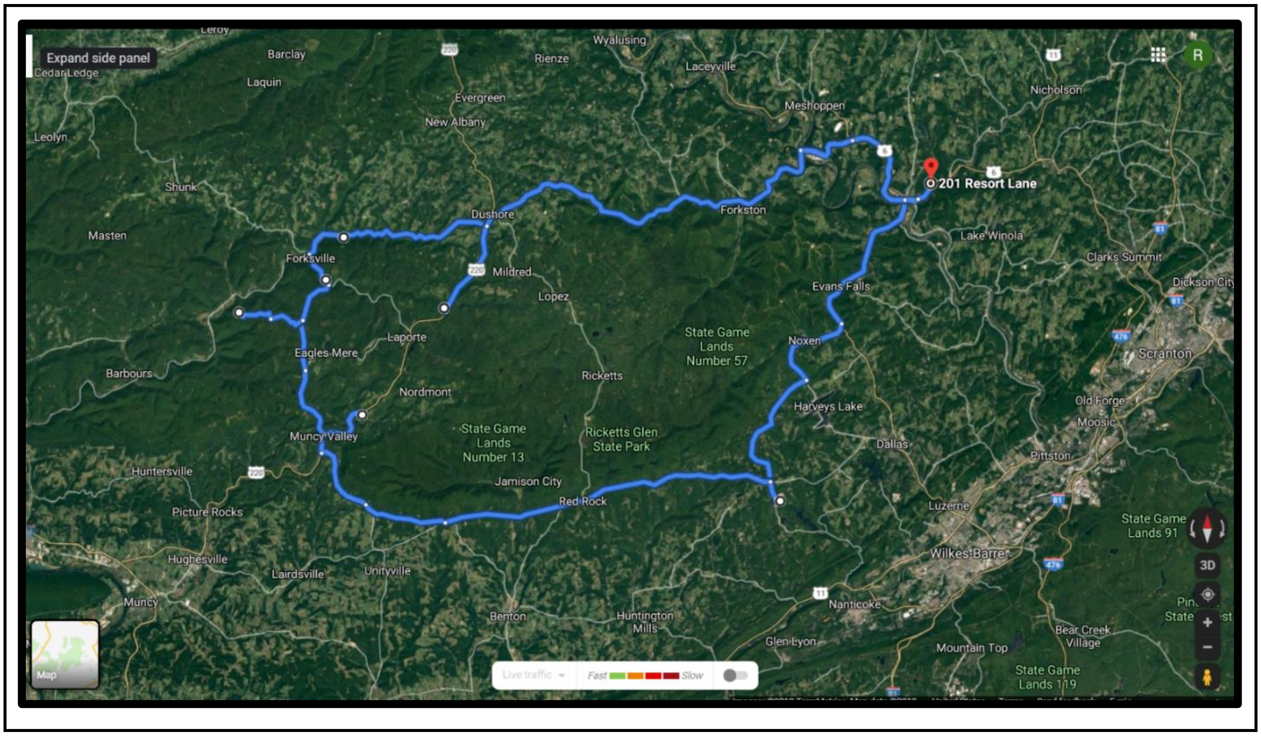


ROADLOG

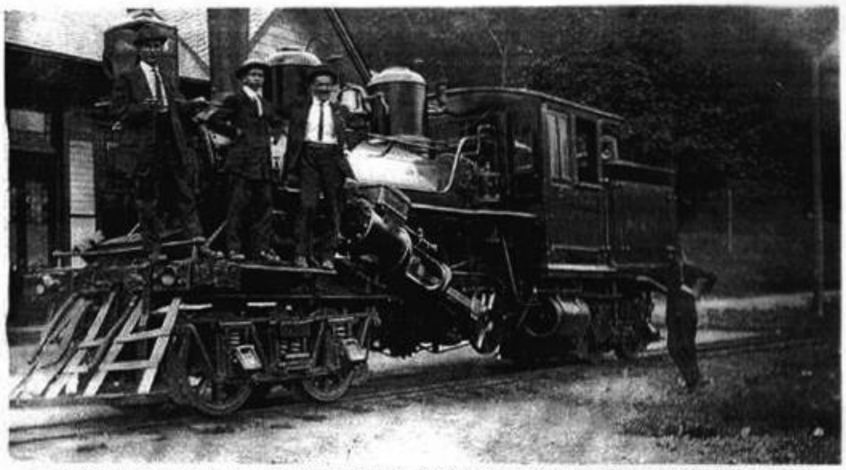

INDEX MAP
NY
PA
NJ
DAY 1
DAY 2
HQ
Endwell
Endicott
Binghamton
Deposit
Susquehanna
Montrose
Tunkhannock
Harveys Lake
Forest City
Carbondale
Honesdale
Prompton Lake
Wilkes-Barre
Ricketts Glen
North Mountain
Themes
Map Layers
Base Map
Environmental Conservation Office_Kirkwood
8
9
Lunch_Kirkwood Veterans River Park
10
Paleosol_Hancock parking
11
Karst and colluvium_Starlight
7
H&K_New Milford quarry
DAY 2
Elk Mountain
12
the undivided Catskill
Catskill differentiated into members
HEADQUARTERS_Shadowbrook Inn
5
Tilted Catskill_Forksville
LUNCH_Worlds End
4
3
High Knob Overlook
Dutchmans Falls
6
DAY 1
Folded Catskill_Sonestown
2
H&K_Pikes Creek quarry
1
LEGEND
DAY 1
route
stop
DAY 2
route
stop
Pennsylvanian
Pap - Allegheny and Pottsville Formations, undivided
Pp - Pottsville Formation
Mississippian
Mmc - Mauch Chunk Formation
Mb - Burgoon Sandstone
Mp - Pocono Formation
Mississippian and Devonian
MDhm - Huntley Mountain Formation
MDsk - Spechty Kopf Formation
Devonian
Dck - Catskill Formation, undivided
Dlh - Lock Haven Formation
Geologic map (PaGEODE) field stops area
Note vast area of undifferentiated Catskill
Refer to Introduction, this guidebook, for discussion on new and previous Catskill mapping

Road Log 2019 FCOPG



Cumulative Mileage	Segment	DIRECTIONS: Day 1, Friday, Oct 4, 2019
0.0	0.0	Head northeast on Resort Lane to US 6
0.2	0.2	Turn right onto US 6 W
1.4	1.0	Keep left on US 6 W
2.2	0.8	Turn left onto PA-29 S (Bridge Street)
11.6	9.4	Keep right on PA-29 S
17.3	5.7	Turn right to stay on PA-29 S
26.2	8.9	Turn left onto Trojan Road (T581)
26.5	0.3	**STOP 1 Pikes Creek Quarry (41.28988, -76.08665)**
		Fun Fact #1: The reddish-brown crystalline sandstone quarried at Pikes Creek is used in the production of (among other things) hot-mix asphalt. Asphalt was used for waterproofing and as an adhesive as early as the fifth millennium BC, and archeologists have found evidence of asphalt used in: the original walls surrounding Babylon, the embalming process for ancient Egyptian mummification, household deity statues in Japan and China, and the waterproofing of aboriginal canoes in Canada.
		Back west on Trojan Road
26.8	0.3	Turn right onto PA-29 N
27.9	1.1	Turn left onto PA-118 W
47.1	19.2	Turn right onto PA-239 N
52.0	4.9	Merge into PA-42 N
56.5	4.5	Turn right onto US-220 N
60.9	4.4	**STOP 2 Folded Catskill (41.36017, -76.54322)**, outcrop on right, buses park on berm

Fun Fact #2: Sonestown, Pennsylvania was founded in 1843 by George Sones. He built a sawmill, which led to a late 19th century business “boom” as the lumber industry grew in Sullivan County. Later, the town hosted factories specializing in lumber-based products: one that manufactured the staves for making barrels, and one that made wooden clothespins.



The Climax locomotive ran on the narrow gauge line to Eagles Mere from Sonestown. The Climax was a geared locomotive designed to handle steep grades and sharp curves. Photo taken soon after E.M.M.R became part of W&NB R.R., indicated by lettering on tender.

caption: The Climax locomotive ran on the narrow guage line to Eagles Mere from Sonestown. The Climax was a grand locomotive designed to handle steep grades and sharp curves. Photo taken soon after E.M.M.R. became part of W&NB R.R., indicated by lettering on tender

Sonestown Hotel, left, and Dr. Hydock house provide background for buggy and a horse with fly netting.

caption: Sonestown Hotel, left and Dr. Hydock house provide background for buggy and a horse with fly netting.

Figures: Early 1900's photos of Sonestown area from Tonya Sones Madison, lifelong resident of Sonestown. Taken from: https://sites.rootsweb.com/~pasulliv/resources/Sonestown.htm

		Continue on US-220 N
66.4	5.5	Turn left onto PA-42 S/Main St (Laporte)
73.9	7.5	Turn right onto Worlds End Road

76.8	2.9	Sharp left onto High Knob Road
79.1	2.3	Turn right onto Forest Road/High Knob Road (one way road)
81.4	2.3	**STOP 3 High Knob Overlook (41.44377, -76.67858)** park in lot on right

Fun Fact #3: From the top of the High Knob Overlook—about 2,020 ft above sea level—it is possible to see mountaintops from seven different counties!

Fun Fact #4: The Bortle scale is a numeric scale that measures the night sky's brightness at a specific location, and ranges from a class 1 (excellent dark-sky site) up through a class 9 (inner-city sky view). The High Knob Overlook has a Bortle-rating of 3…a rural sky view! This means that zodiacal light is visible in spring and autumn. Zodiacal light (also called a "false dawn" when seen before sunrise) is a faint, diffuse, and roughly triangular white glow that is visible in the night sky and appears to extend from the Sun's direction and along the zodiac, straddling the ecliptic. This phenomenon occurs when sunlight is scattered by interplanetary dust clouds.

		Continue northwest on Forest Road
82.6	1.2	Turn left on Forest Road/High Knob Road (end one way road)
86.3	3.7	Turn left on Worlds End Road
89.1	2.8	Turn left onto PA-154 W (Cabin Bridge Rd)
89.5	0.4	**STOP 4 LUNCH (41.47050, -76.58359)** Worlds End State Park turn right into parking lot

Fun Fact #5: The earliest recorded inhabitants of the Worlds End State Park were natives of the West Branch Susquehanna River valley. These peoples were the Susquehannocks—a matriarchal society that spoke the Iroquois dialect. On November 5, 1768, the Province of Pennsylvania acquired the New Purchase from the Iroquois (who had amassed the land through extended warfare with the Susquehannocks) in the Treaty of Fort Stanwix. This purchase included what is now known as Worlds End State Park.

Bonus fun fact: Susquehannock society never allowed women to become elected leaders, but the women of these small villages had the collective power to "impeach" the current chieftain if they were unsatisfied with his work.

Fun Fact #6: In 2010, Worlds End was part of over 2,600 acres of state forests and parks combating the invasive woolly adelgid. A $110,000 federal grant was awarded to the DCNR's "Forest Pest Management Division for insecticide treatment of high-value Eastern hemlocks."

(Photo showing evidence of hemlock wolly adelgid on western hemlock tree. Image by Connecticut Agricultural Experiment Station Archive, Connecticut Agricultural Experiment Station / © Bugwood.org, CC BY 3.0 us, https://commons.wikimedia.org/w/index.php?curid=8339006.)

		exit parking lot turn right
91.5	2.0	Turn right onto PA-87 N
94.2	2.7	**STOP 5 Tilted Catskill (41.50565, -76.56495)** outcrop on left

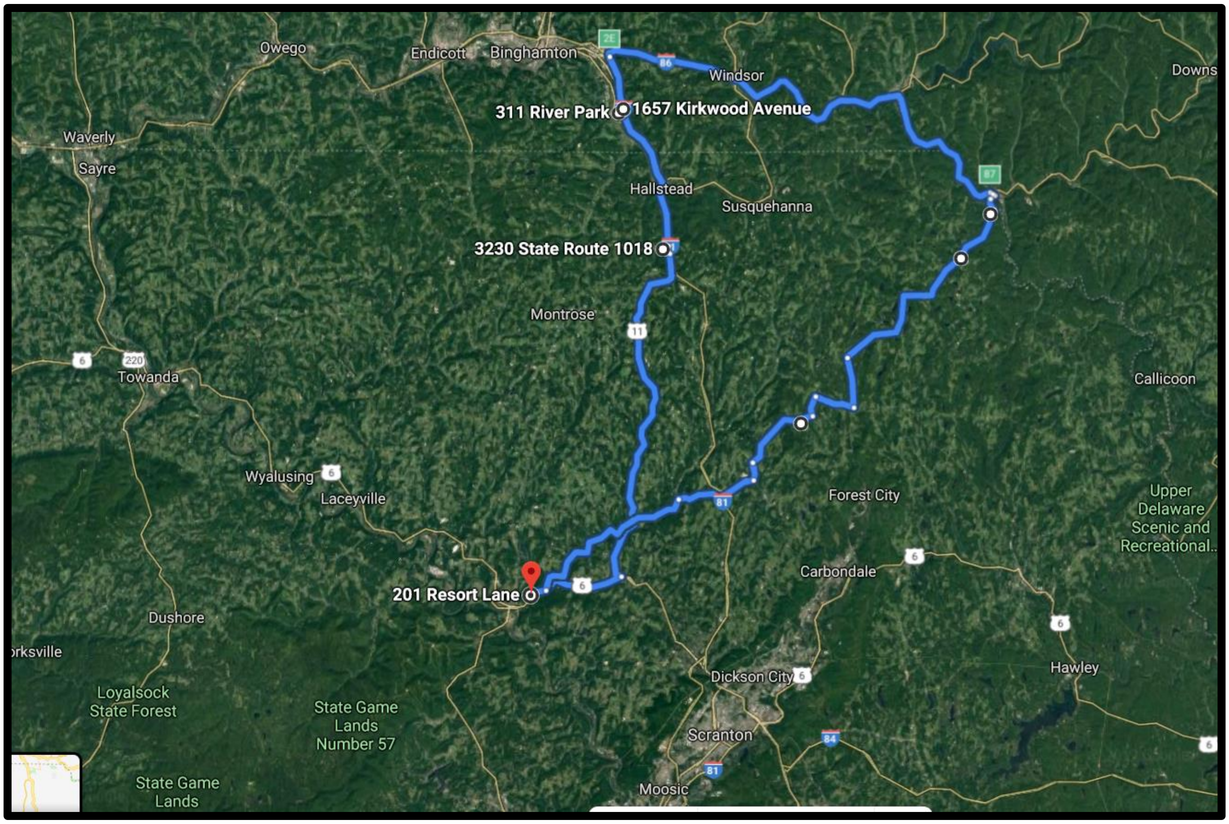
Fun Fact #7: Harold Edward "Red" Grange (a.k.a. "The Galloping Ghost"), who was a College and Pro Football Hall of Famer, was born in Forksville, PA. Sports historians believe that his signing with the Chicago Bears in 1925 helped legitimize the NFL. At the time, professional football was viewed as a commercialized, weaker brand of its college counterpart; Grange's popularity went a long way toward increasing public approval of the NFL.

(Photo showing Harold Edward "Red" Grange. Image by National Photo Company Collection, Library of Congress. This image is available from the United States Library of Congress's Prints and Photographs division under the digital ID npcc.15254, Public Domain, https://commons.wikimedia.org/w/index.php?curid=6193790.)

		continue east on PA-87 N
103.6	9.4	Turn right onto US-220 S
109.3	5.7	Turn right onto Mead Road
109.5	0.2	**STOP 6 Dutchman Falls (41.44768, -76.45373)** bus parking on left.

Fun Fact #8: During the American Revolution, nearly half of the state's population was comprised of Pennsylvania Dutch settlers. Despite having strong pacifist values, the Pennsylvania Dutch were generally strong supporters of the Patriot side!

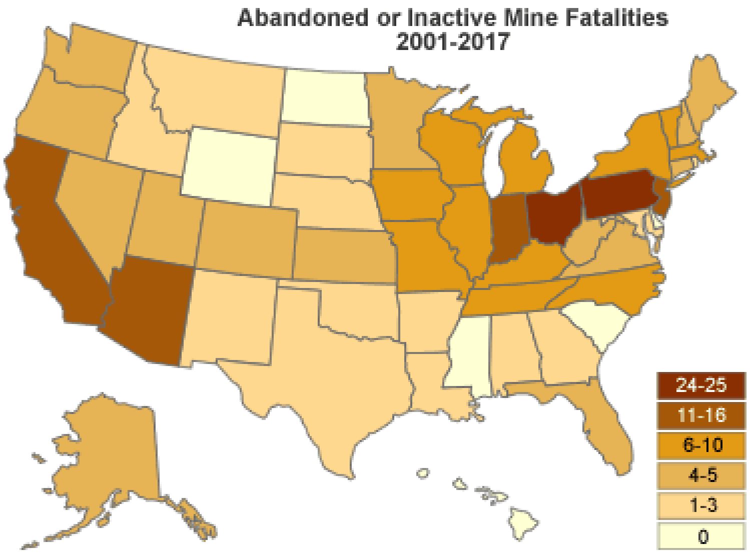
		back down Mead Road to US-220
109.7	0.2	Turn left onto US-220 N
116.1	6.4	Turn right onto PA-87 N (East Main Street)
116.1	300 ft	Slight veer left to continue on PA-87 N (Mill Street)
116.3	0.2	Turn left to stay on PA-87 N (Carpenter Street)
138.6	22.3	Turn right to stay on PA-87 N
		Just past Proctor & Gamble plant get in right lane
142.2	3.6	Turn right onto US-6 E
146.4	4.2	Veer right on US-6 E
150.0	3.6	Turn left onto Resort Lane



Cumulative Mileage	Segment	Directions: DAY 2
0.0	0.0	Depart **Shadowbrook Resort** heading northeast on Resort Lane toward US-6 W
0.2	0.2	Turn left onto US-6 East
7.2	7.0	Merge onto US-11 North
33.4	26.2	Turn left onto State Rte 1018
34.1	0.7	Turn left to stay on State Rte 1018 Franklin Hill Road
34.6	0.5	Quarry will be on the right

Stop 7 H&K Quarry New Milford 41.900290, -75.742020

(Not so) Fun Fact: Drowning is the number one cause of death in abandoned mines… and Pennsylvania has the second highest number of abandoned mine fatalities in the country! This risk is largely influenced by very cold water temperatures: since many quarry operations excavate below the water table, when operations cease the area is flooded with cold groundwater. As explained by the National Institute of Health, the abrupt drop in skin temperature that occurs when jumping into very cold water elicits a powerful cardiorespiratory response called "cold shock." The body's respiratory system responds to cold shock with an involuntary gasp, hypertension, and hyperventilation. These responses override conscious and other autonomic respiratory controls.



(Image from Geology.com using data from newspaper articles and the Mine Safety and Health Administration. Accessed at: https://geology.com/articles/abandoned-mines.shtml.)

		Head east on State Rte 1018 toward Old Lackawanna Trail
35.1	0.5	Turn Right to stay on Rte 1018
35.2	0.1	Turn Left onto T689 School Road
35.3	0.1	Turn Left onto US- 11 North
		Entering New YorK State
45.9	10.6	NY DEC Flood Control Training Center on Right
		Stop 8 NY DEC Flood Control Center 42.041896, -75.796524

Fun Fact: Kirkwood, NY, was named after James Pugh Kirkwood. Mr. Kirkwood was a Scottish-born civil engineer who spearheaded the construction of the Erie Railroad, which runs through the town.

(Photo showing the Erie Railroad in Kirkwood, NY, in front of the Susquehanna River. Image from the Town of Kirkwood, accessed at: http://www.townofkirkwood.org/history/.)

		Turn left & head southeast on US-11 S
46.1	0.2	Turn Left onto ramp to I-81/ NY-7
46.3	0.2	Turn Left onto Kirkwood Conklin Rd

46.8	0.5	Turn Left onto Bridge Street
47.1	0.3	Turn Left onto Main Street
47.3	0.2	Turn Left at Brown sign for Veterans Park entrance
47.5	0.2	Turn Left in the park to head back to Pavillion 1 & 2

STOP 9 LUNCH Veterans Park 42.038091, -75.802367

Fun Fact: The word "lunch" is an abbreviation of the more formal Northern English word luncheon. This word is in turn derived from the Anglo-Saxon noun nuncheon or nunchin, which means "noon drink." So enjoy your nuncheon, and stay hydrated!

47.7	0.2	Turn right out of the park
47.9	0.2	Turn right onto Main Street
48.4	0.5	Turn Right onto Bridge Street
49.0	0.6	Turn Right onto Kirkwood Conklin Rd
49.3	0.3	Take ramp for I 81 North merge onto I-81N
52.9	3.6	Take exit 2E to merge onto I-86 E/NY-17 E toward I-86 E/New York
62.0	9.1	Continue onto NY-17 E
88.3	26.3	Take exit 87 for NY-97 toward NY-268/PA-191/Hancock/Cadosia
88.5	0.2	Turn left onto NY-97 S/W Front St/W Main St
88.5	489 ft	Turn right onto W Front St/W Front St Exn
88.7	0.2	Turn right onto S Pennsylvania Ave
		Entering PA
89.1	0.4	Continue onto PA-191 S
90.0	0.9	Turn right onto PA-370 W

Stop 10 Paleosol Waterfall Pull off along right side of road 41.935368, -75.294371

Paleosols can be very important for paleobotany and reconstructing paleoecologies! Besides often containing ancient plant material and phytoliths (a biomineralized form of silica produced by plants like grasses), the carbon isotopic signature of paleosols can offer insight into past temperatures and biomes. The ratio of heavy-to-light carbon isotopes in paleosols reflects the ratio of plants using C3 photosynthesis (which typically grow in cooler and wetter climates) versus plants using C4 photosynthesis (which generally grow in hotter and drier climates).

90.0	0.0	Turn left into Cow Palace parking lot on the corner of Rose Hill Road and Crosstown Highway
94.1	4.1	**Stop 11 RT 370 Waterfall Karst 41.889322, -75.338588**

Fun Fact: Starlight, PA has multiple haunting legends. The weirdest and most interesting legend is from the mid 1800’s and involves a Frenchman who (allegedly) learned how to be a Voodoo priest in Haiti. He apparently cursed the owner of a local poultry farm because the farmer refused to let the Frenchman marry his daughter and sacrifice chickens during the wedding ceremony. The curse worked! The farmer’s daughter died shortly thereafter in a horse-riding accident. Legend has it that she was so distraught about not getting to marry the French Voodoo priest that she took an emotional and reckless ride through the woods during a storm, got clotheslined by a tree branch, and died.
>>>>>> This is the most hilarious fun fact ever.

106.3	12.2	Turn left onto PA-171 S
109.8	3.5	Turn right onto PA-374 W
112.6	2.8	Turn left to stay on PA-374 W
114.1	1.5	Turn right to stay on PA-374 W
115.3	1.2	Turn left onto Elk Mountain Rd Destination on right
115.6	0.3	**Stop 12 Elk Mountain Stop 41.723405, -75.553427**

Fun Fact: Elk Mountain is the highest peak of the Endless Mountains—a geographical, geological, and cultural region in Northeastern Pennsylvania. Geologically speaking, the Endless Mountains are not true mountains. They are part of a dissected plateau—a plateau area that has been severely eroded so that the relief is sharp. Consequentially, Elk Mountain does not have the folding, metamorphism, extensive faulting, or magmatic activity associated with a traditional orogeny.

	0.0	Head northwest on Elk Mountain Rd toward PA-374 E
115.9	0.3	Turn left onto PA-374 W
120.8	4.9	Turn left onto PA-106 E/PA-374 W
122.1	1.3	Turn right onto PA-374 W
128.1	6.0	Turn left onto PA-92 S
141.5	13.4	Turn right onto US-6 W
142.5	1.1	Turn right onto Resort Ln
142.8	0.2	**Arrive Back at Shadow Brook Resort Safe Travels 41.549502, -75.919671**

HARPER'S GEOLOGICAL DICTIONARY

DENUDATION - The act of getting dressed.

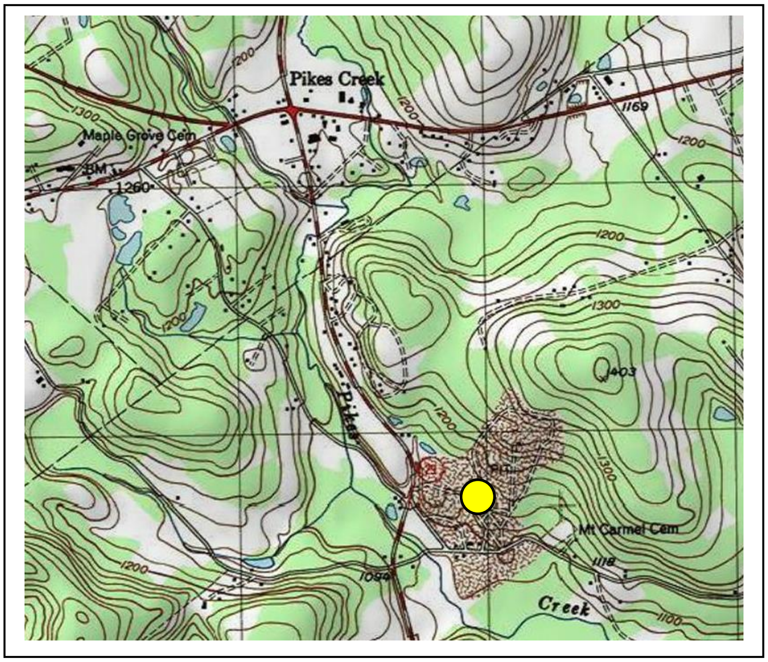
Stop 1. Redbeds and the fining-upward cycle, the Pikes Creek Asphalt Quarry

Discussant: Bill Kochanov, Pennsylvania Geological Survey (retired)

The site is located at 528 Trojan Rd, Hunlock Creek, PA, approximately 1 mile southeast of the intersection of SR29 and SR119.

There will be two stops in this quarry. The buses will take us up the haul road, drop us off on the first bench, and after a discussion and examination of the rocks, we will walk back down the haul road to where the buses are parked on the pit floor. There we will hear part two of the discussion and enjoy refreshments while we ponder a unique, recently discovered sedimentary structure/fossil.

Coordinates: 41.294752°, -76.084676° (Figure 1.1).



This is an active quarry. Standard safety rules apply with hard hats, steel toe/field boots, and safety vests a must have. Do not go beyond the rock piles towards the highwall or towards the edge of the pit floor highwall, it's a long way down. We are here at the courtesy of H&K and would like to continue being good, conscientious rockheads.

Figure 1.1. Location map for Stop 1, Pikes Creek Asphalt Quarry. North is up.

Observations

The highwall provides a three-dimensional view of the depositional setting, highlighting the repetitive nature of the fining-upward cycle. In a casual glance one can't help but notice the predominance of redbeds and relatively minor occurrence of the greenish-gray sandstone beds.

Best seen from the pit floor looking north, is a wedge of stacked, thin to medium bedded, gray sandstones tapering from east to west (Figure 1.2). Note that when tracing the same bed onto the western highwall, the beds are near horizontal. The western highwall also shows a regular spacing between the sandstone beds (Figure 1.2a). This represents a series of stacked fining-upward cycles, each cycle starting with a sharp and undulatory basal contact, followed by medium-bedded, light greenish-gray, medium-grained, laminated sandstones. The sandstones grade upward into greenish-gray silty shales intermixing with grayish-red, very fine-grained sandstones to silty shales and medium-gray, silty, claystone shale before becoming all reddish gray shales, shale/claystones, and mudstones.

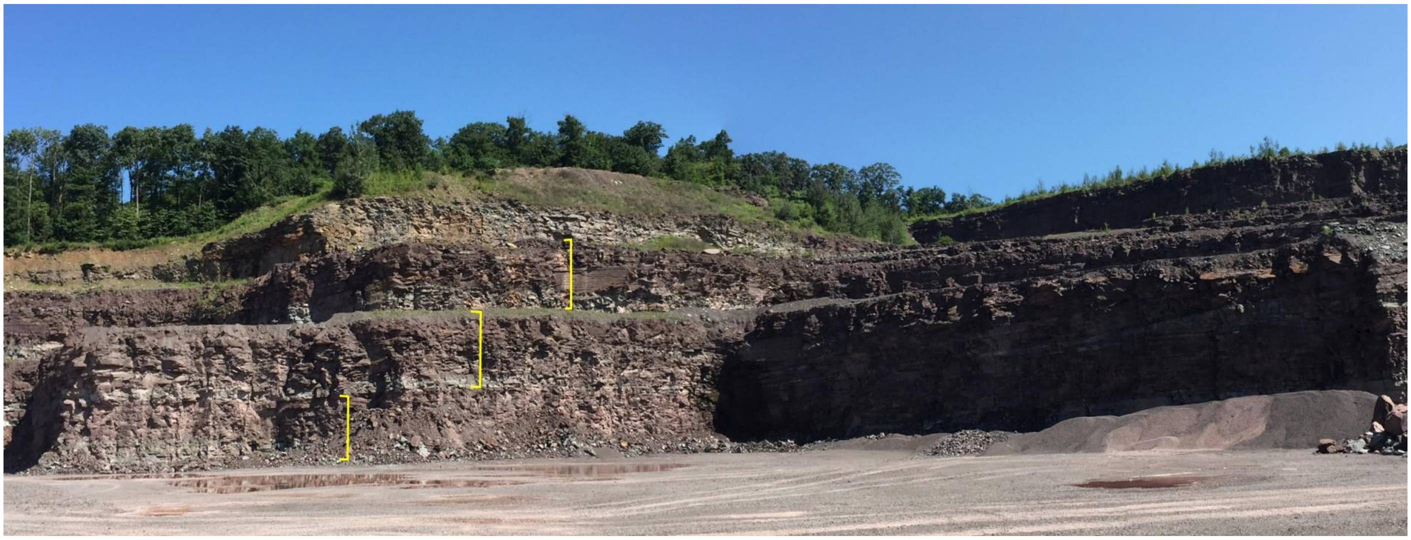


Figure 1.2. View of the pit floor looking northwest. Yellow bars on the western highwall showing approximate thickness of individual fining-upward cycles. Bars are approximately 4 meters in length.

Figure 1.2a. Northern highwall of pit floor showing east to west, tapering, basal sandstone of fining-upward cycle. Note similar sandstone at the base of the photo.

The lower contact of the "wedge" sandstones is generally sharp and undulatory with the redbeds. The erosive base of the sandstone commonly contains a thin (less than 10 cm) layer of calcareous intraformational conglomerate or agglomerate. This is representative of the flush of sediments from the Devonian highlands, becoming bedload in the main river channel and either being draped atop the levees or being added to the base of the river channel as lag deposits. These agglomerates typically consist of rounded sandstone pebbles, fossil plant fragments, rip-up shale clasts and the rare fish fossil bone ranging from sand size to 10 cm were carried over the levees at peak flood time. The calcareous clasts were likely derived from pedogenic sources (paleosols) which commonly contain calcareous glaebules and nodules or possibly from fresh-water carbonates associated with interdistributary lakes.

These features can be examined in much more detail on the upper bench. Note that the sequence occurring at the main level of the quarry highwall repeats on the upper levels. This repetitive cycle provides some insight into the seasonality of this exposure of the Catskill, basically inferring an established flood basin of silts and muds that was fed by sediments sourced from periodic (annual or seasonal) flood events.

The exposure in this quarry is only showing the sediments of the flood basin – the actual channel would be somewhere off to the east.

Up top

The upper bench provides an opportunity to examine a broad range of the fine-grained redbed lithologies as well as the greenish gray sequence of sandstones and silty shales.

Most interesting are the variety of sedimentary structures that can be found among the redbed blocks. A sampling can be viewed in Figure 1.3. The structures are representative of those commonly occurring in the redbeds, however, they are by no means restricted to them. In addition, there are trace fossils, consisting of several types of burrowing structures (Figure 1.4) and fossil plants represented by the genus *Archaeopteris* possibly *halliana?* (Figure 1.5), a variety of root fossils and "tree bark" impressions (Figure 1.6).

Figure 1.3. Sedimentary structures. From left to right, A. mudcracks, B. asymmetrical ripple marks, and C. load casts. Hammer length 28 cm.

Figure 1.4. Trace fossils from the redbeds on the upper bench. A. Plane view of oval shaped burrow *Beaconites? sp.,* B. an indeterminate crawling trace, hammer length 28 cm and C. a much larger vertical burrow *Hyperoeuthys? sp.* infilled with greenish-gray silty shale. Yellow bar approximately 45 cm.

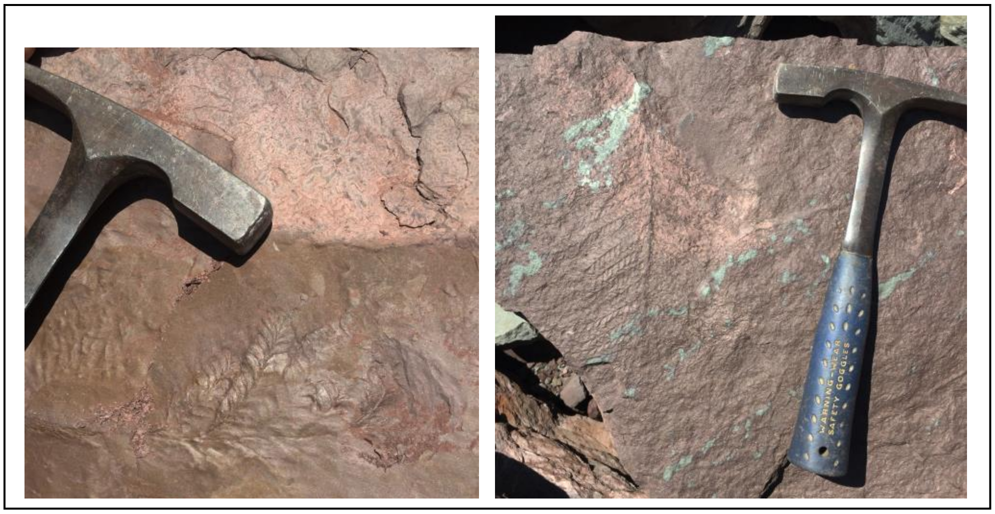


Figure 1.5. Compressions of plant fossil *Archaeopteris halliana?* Hammer length 28 cm, hammer head 18 cm.

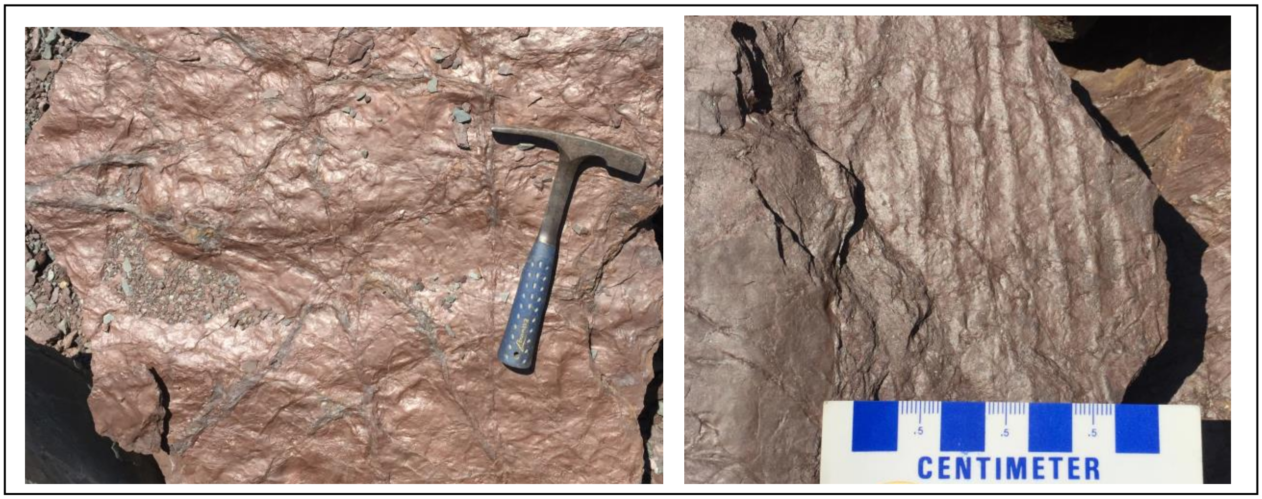


Figure 1.6. Fibrous interconnecting fossil rootlets (left) and "tree bark" (right) compression. Hammer length 28 cm.

A closer examination of the scattered greenish-gray sandstones blocks displays calcareous intraformational conglomerate or agglomerate (Figure 1.7).

Figure 1.7. Calcareous agglomerate (left) displaying a wide range of cobbles, pebbles, and clasts. Note the thin bed of reddish gray agglomerate (right, end of hammer) and the reddish-gray calcareous laminations alternating with the greenish-gray sandstone laminae. The red coloration is from the oxidized iron within the carbonate residuum.

Based on the sedimentary structures and fossil evidence observed on the upper bench, the flood basin had a history of moderate stability punctuated by periodic flood events. The relative flatness of the redbeds can be attributed to the relatively low slopes at the distal ends of the levees.

The plant root traces across the bedding surfaces provides at least cursory evidence that plants were either established or readily colonized the silty muds of the flood plain basin. Plant fossils like the *Archaeopteris* may have been part of the established riparian flora but it is more likely they were washed into the flood basin.

The Mystery Structure

Discovered by quarry workman, this unique sedimentary feature poses an interesting inquiry as to its genesis. First impression reminds one of multiple palm branches – a series of leaves emanating from a central "midline" ranging in length from 25 to 45 cm and "leaves" 3 to 7 cm in length (Figure 1.8). No leaf impressions are observed. If they are plant-related features, perhaps the stems were stripped of leaves prior to deposition and subsequently covered with a thin veneer of mud.

In contrast, one can also envision the "midline" serving as miniature ridge crests with the "leaves" miniature parallel rills. The orientation of bedding is reversed, so one is viewing the top – the cast of the mold. The structure represents the infilled mold of miniature "v-shaped valleys" complete with miniature erosional rills (Figure 1.8).

Figure 1.8. Mystery block on pit floor showing unique sedimentary structures. Note the similarity to floral branching and a miniature erosional landscape. Seven cm scale on left image. Sunglasses frame 14 cm in length.

HARPER'S GEOLOGICAL DICTIONARY

FINING-UPWARD SEQUENCE - A progression of increasingly disciplinary financial penalties imposed on sedimentary geologists for repeated scientific infractions.

Stop 2. Folding in the Catskill Formation along U.S. 220

Discussant: Brett McLaurin, Bloomsburg University

Authors: S. Christopher Whisner, Jennifer Whisner and Brett McLaurin
Department of Environmental, Geographical and Geological Sciences, Bloomsburg University

The site is approximately 1.4 miles northeast of Sonestown, along U.S. Highway 220 North (Figure 2.1)
Coordinates: 41.360138, -76.543278

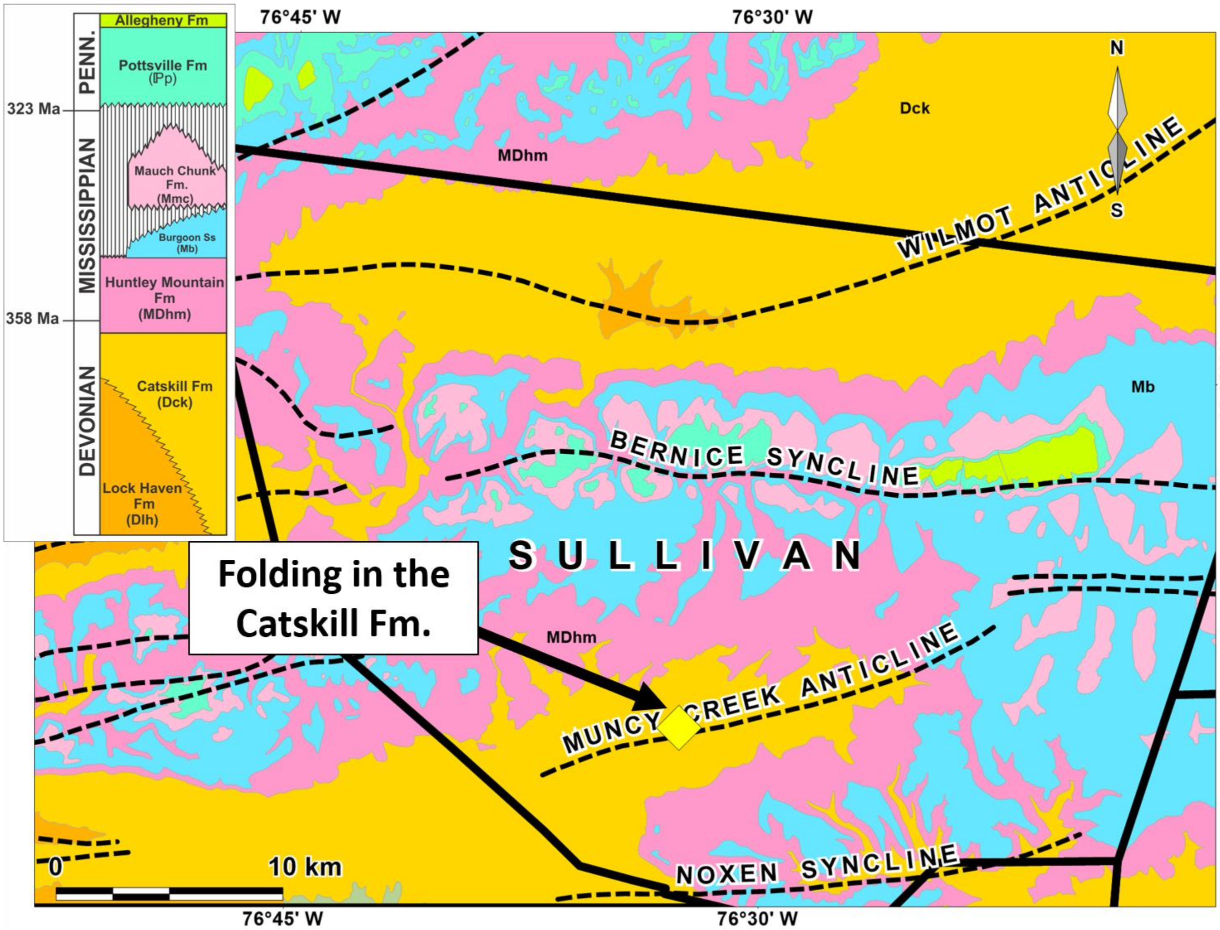


Figure 2.1. Geologic map of the Appalachian Plateau Province in northern Pennsylvania, denoting the area of deformation with regional geology and principal geologic features. Geology from Berg et al. (1980). Fold axis location modified from Faill (2011). Stratigraphic chart modified from Berg (1993).

Key Points

1) Small-scale folding in the Catskill Formation
2) North limb of Muncy Creek anticline
3) Anticline-syncline pair with beds dipping as steeply as 60°
4) Result of fault propagation folding related to a blind-thrust below road level (localized west-southwest shortening)

Introduction

We have stopped in the Appalachian Plateau physiographic province, which is dominated by long wavelength (> 1km) and low amplitude folding (Figure 2.1). In this location, we are just north of the Muncy Creek anticline cored by the Devonian Catskill Formation. The fold axis of this anticline trends around 75° and plunges gently to the east-northeast. Other regional folds, such as the Bernice Syncline to the north and the Noxen syncline to the south, have more east-west trends. Most bedding in this area dips either south or north between 5-10°.

Geologic Structures

The outcrop we are looking at is near the hinge of the Muncy Creek anticline and is worth a stop because of its several anomalous structures. First, the rock in this outcrop is folded and contains an anticline-syncline pair with beds dipping as steeply as 60° (Figure 2.2). This is highly unusual, but not unknown for this part of the Plateau. The Catskill Formation, here, consists of very fine to fine-grained sandstone and clayshale that represent deposition in fluvial channels. The channel features and variable-thickness layers may combine with the structural deformation to produce the unusually steep bedding. Another anomaly is the orientation of the folds. The fold axis of the anticline with the steeply dipping forelimb at the base of the outcrop is oriented 8°, 145°, and the fold axis of the adjacent syncline is 2°, 172° (Figure 2.3). These orientations are between 45° and 100° from the orientation of the regional anticline and the orientations of the two adjacent regional synclines. The only regional-scale fold in the Pennsylvania Plateau with a similar orientation lies 24 km to the northwest on the Lycoming/Sullivan county border. The strange fold orientations may be due to 1) a room problem in the hinge of the larger anticline, 2) the varying thickness and competence of layers due to sedimentary features such as cross beds and channel deposits, 3) both of these, or 4) something else entirely. Adding to the oddities, the single, poor slickensurface identified in the outcrop indicates one of the lower beds in the outcrop was moving along an orientation of 9°, 200°, with top-to-the-north. This does not coincide with the presumed north-northwest direction of shortening of the larger structures in the area, nor does it match the local direction of shortening inferred from the two folds in the outcrop (west-southwest).

Figure 2.2: Panoramic photo of folds in an outcrop of Devonian Catskill Formation along U.S. 220 north of Sonestown, PA. The photo was taken looking to the southeast. Red lines indicate faults. Blue lines show bedding.

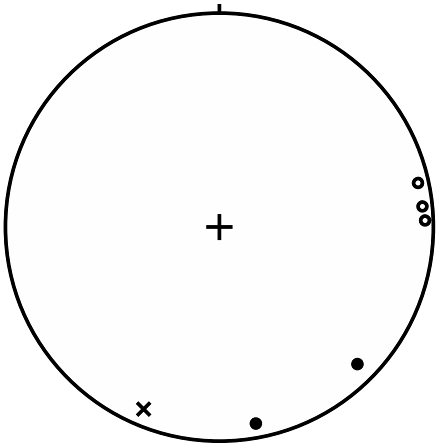


Figure 2.3: Orientations of outcrop fold axes (closed circles), regional fold axes (open circles), and slickenline (x).

Discussion

For other steeply dipping Plateau structures you will see on this trip, the case can be made for anomalous vergence (structures verging opposite the direction of shortening) see Mount (2014), for example. Here, it seems most likely that the folds were created by movement closer to the regional direction of shortening. This folding is difficult to attribute to a particular model but seems likely to be some variety of fault-related folding. The geometry of the folds is best observed from the west end of the anticline at an oblique angle to the outcrop, giving a view that is close to down-plunge. The shape of the folds (steep common limb between the anticline and syncline) suggests they may be the result of fault propagation folding (FPF) (Figure 2.4). We suggest that the folding here is related to a blind thrust below the road level. There is no indication of an out-of-the-syncline thrust in the outcrop, suggesting that we may be above the tip of the fault. Faults within the outcrop do not match classic FPF geometries, however. In addition, for any type of fault-related folding, the beds directly above the deformed zone should also be deformed in response to shortening of the underlying beds, and we do not observe that in this outcrop. It is difficult to make grand interpretations with a sample size of one! An examination of bedrock outcrops along roads in the area did not uncover any similar structures.

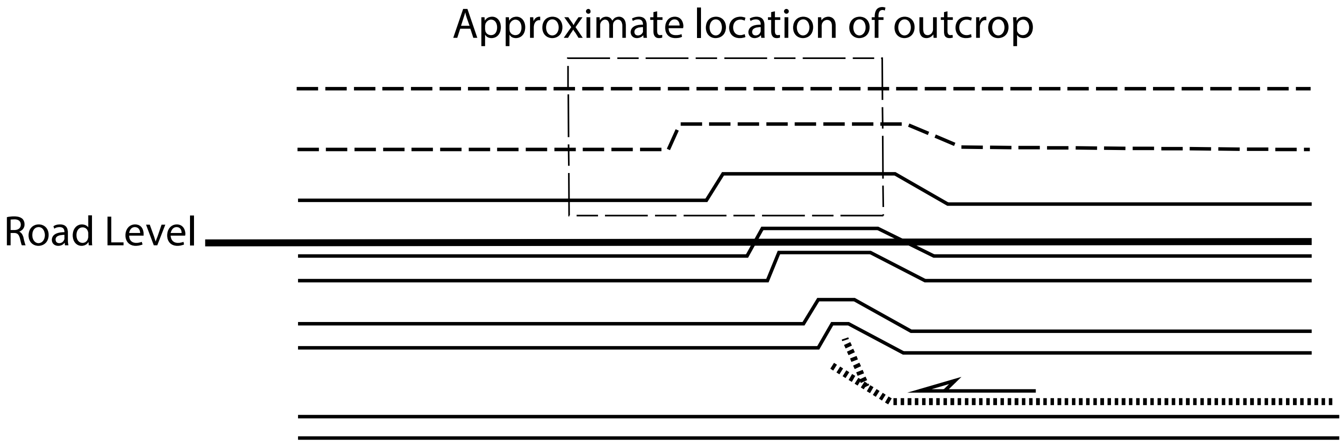


Figure 2.4: Diagram (not to scale) showing possible development of folds in Catskill Formation along U.S. 220 as fault propagation folds, with detachment and fault tip lying well below the road surface (depth unknown). Bedding at the top of the diagram is dashed due to the incomplete exposure in the outcrop making it difficult to determine the relationship between the folded beds near road level and the apparently horizontal beds above.

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Berg, T.M., Edmunds, W.E., Geyer, A.R., Glover, A.D., Hoskins, D.M., MacLachlan, D.B., Root, S.I., Sevon, W.D. and Socolow, A.A., 1980, Geologic map of Pennsylvania: Pennsylvania Geological Survey, 4th ser., Map 1, 2nd ed., 3 sheets, scale 1:250,000.

Mount, V., 2014, Structural Style of the Appalachian Plateau Fold Belt, North-Central Pennsylvania, Journal of Structural Geology, v. 69, p. 284-303. doi: 10.1016/j.jsg.2014.04.005

He was demonstrating some new karate moves he learned recently, and then there was this ominous "click"!

Stop 3. High Knob Overlook

Discussant: Kristen Hand, PAGS

Author: Stuart Reese, Pennsylvania Geological Survey

High Knob Overlook is an outstanding geologic feature (Reese, 2016) and one of the prime vistas of Loyalsock State Forest (DCNR, 2019). Attendees of the 2006 Field Conference of Pennsylvania Geologists visited this site as Stop 14; Braun (2006) emphasized changes that occurred during the Quaternary Period. The overlook is located in Hillsgrove Township of western Sullivan County in the Hillsgrove 7.5-minute quadrangle. There is a viewer's guide to the panoramic majesty sprawling to the south and west (Figures 3.1 and 3.2). The elevation here is at about 1,997 feet, and the highest elevation at High Knob Overlook is 2,028 feet (2005 PAMAP lidar).

Coordinates: 41.44377°, -76.67858°

Figure 3.1. Overlook viewer's guide.

Figure 3.2. Panorama from Overlook.

The viewshed (Figure 3.3) derived from lidar data extends about 20 miles to the west. About 17 miles to the west is Shoe Knob at 2,150 feet elevation on State Game Lands 133. The location is at 41.41396, -77.00549. The farthest spot, 42 miles away, a sliver of Bald Eagle State Forest on the northeast extension of

Nittany Mountain ridge and Bald Eagle Mountain in the Ridge and Valley physiographic province, may be visible on the clearest of days. It is in the direction just to the left beyond Smiths Knob, which is located about 10 miles to the southwest. The viewer's guide identifies additional topographic features that can be seen.

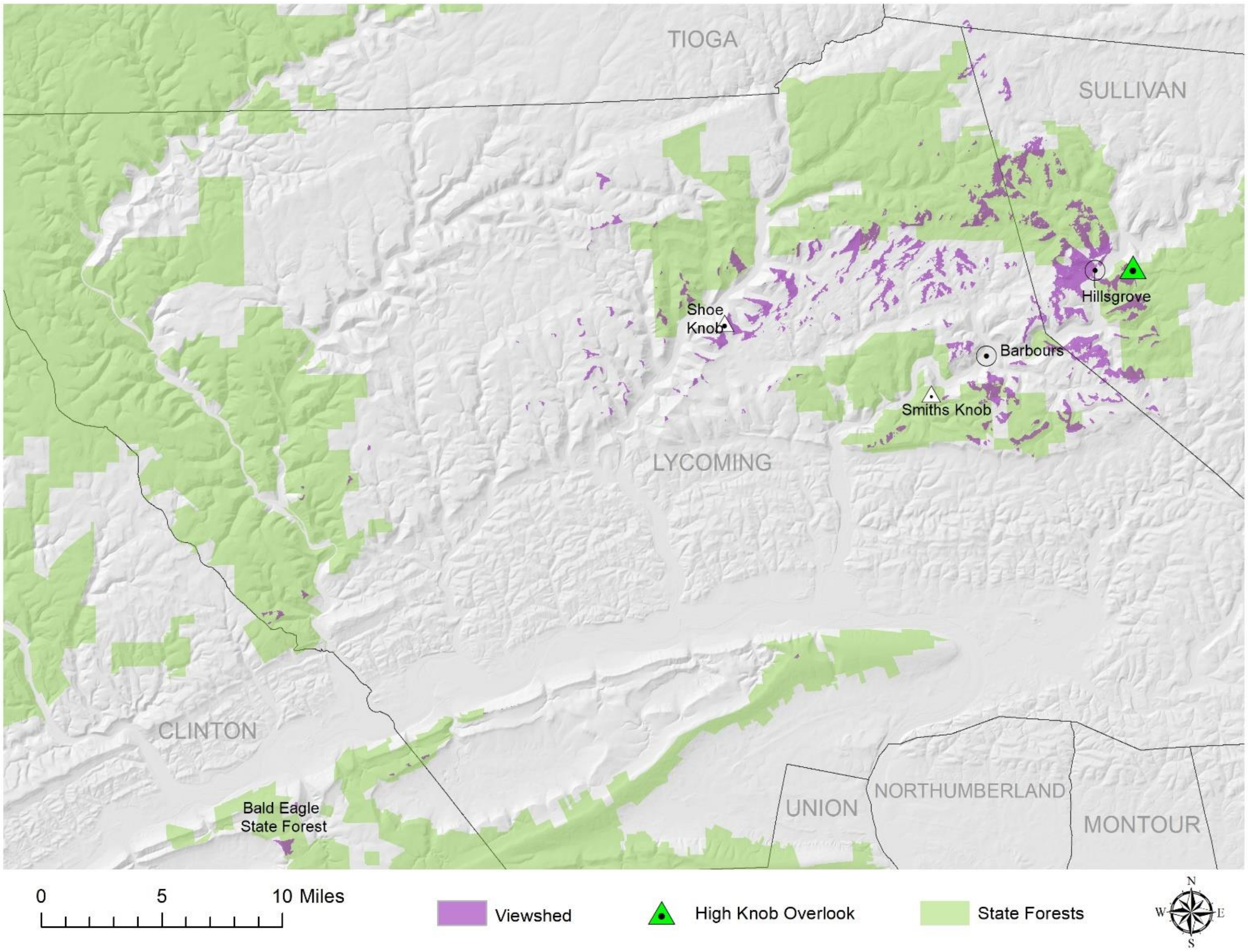

Figure 3.3. Viewshed from Overlook.

In the valley below about two miles away, Loyalsock Creek flows past the unincorporated rural community of Hillsgrove and exits view at about 820 feet elevation, nearly 1,180 feet lower than the vista point. The Loyalsock and tributaries drain 303 square miles upstream of Hillsgrove, which is nearly all of the northern two-thirds of Sullivan County. Forested land cover in this drainage area is 86 percent, according to U. S. Geological Survey's StreamStats (2019).

The valley bottom is underlain by the Catskill Formation, except where the Barbours syncline crosses (Figure 3.4). Despite this structure, bedrock of the surrounding area is basically flat lying with dips typically less than 5°. Above the Catskill is the Huntley Mountain Formation, which is predominantly a micaceous sandstone. It has gradational contacts both with the Catskill below and the Mississippian Burgoon Sandstone above. The Huntley Mountain and Burgoon comprise most of the slopes that can be seen (Figure 3.5). Although a relatively thin unit, the Burgoon Sandstone is very resistant. It thus acts a cap for much of the visible highland, though there are some higher areas topped with Mauch Chunk for flavor.

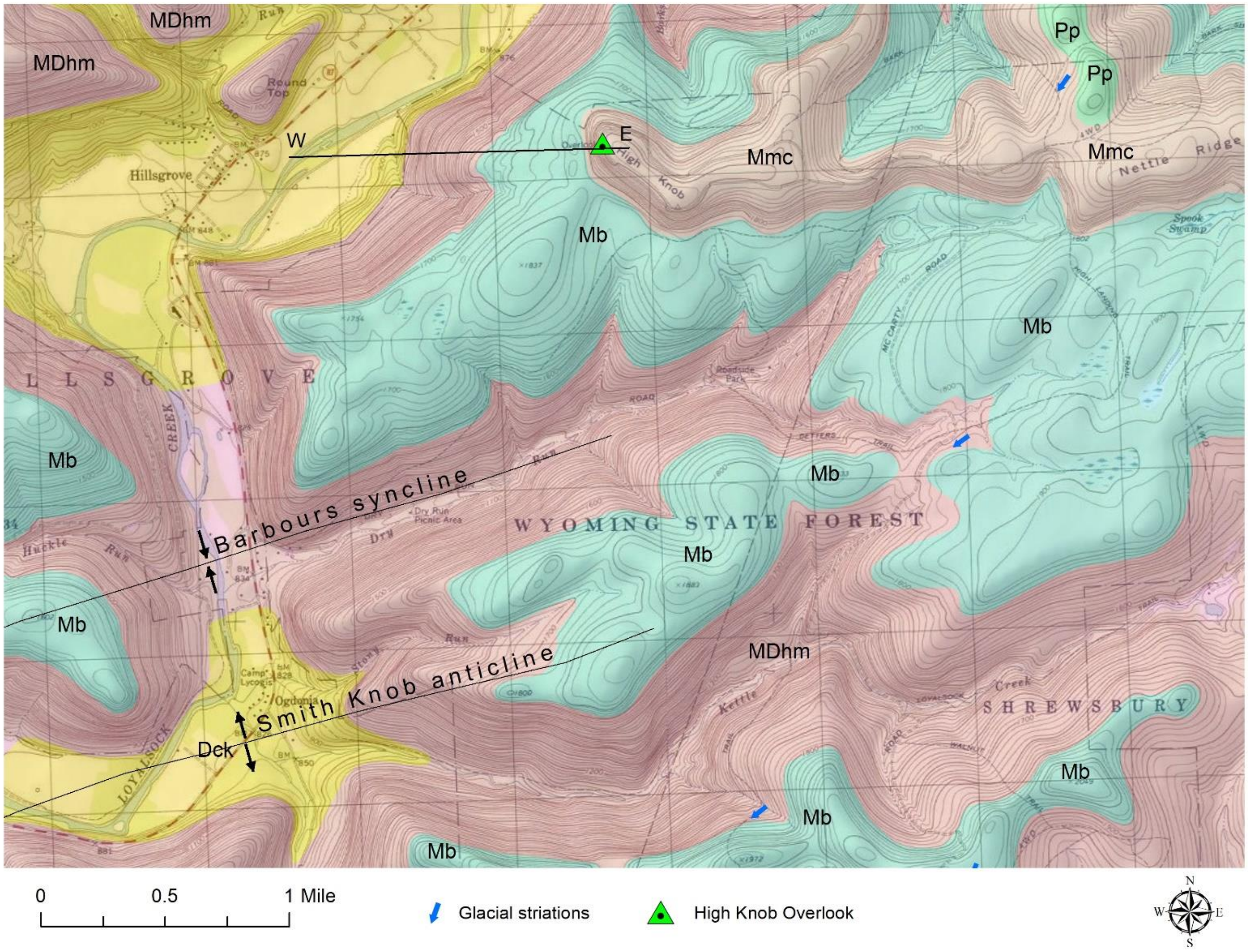

Figure 3.4. Bedrock geologic map showing cross-section location (Figure 3.5) and direction of glacial striations (Braun, 2005). Bedrock units are Mauch Chunk (Mmc), Burgoon Sandstone (Mb), Huntley Mountain (MDhm), and Catskill (Dck). Note: Portions of three state forests including Wyoming State Forest were combined in 2005 to create Loyalsock State Forest (DCNR, 2019).

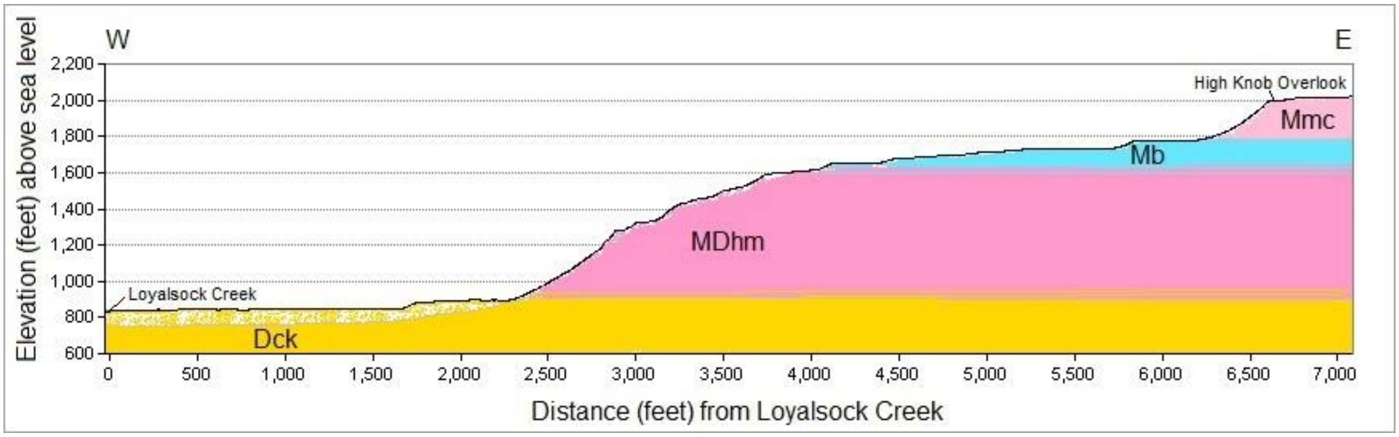

Figure 3.5. Cross section due east from Loyalsock Creek to High Knob showing bedrock units and unconsolidated glacial outwash and alluvium in the valley.

Sandstone and siltstone of the Mauch Chunk Formation (Mississippian age) is the bedrock at the overlook. Stratigraphically above the Mauch Chunk is the Pottsville Formation. It's preserved as isolated remnant caps, including a couple of hills north of Nettle Ridge along High Knob Road. Pottsville sandstone and conglomerate are Pennsylvanian age and underlie the highest elevations of the area to the north and east. The Mauch Chunk-Pottsville contact marks a major erosional unconformity at the Mississippian-Pennsylvanian boundary. The rugged relief of this portion of the Deep Valleys section of the Appalachian Plateaus physiographic province owes itself to the resistant caps of Burgoon Formation and to a lesser extent the Pottsville Formation, and older, softer geologic units in the valley bottoms.

Braun (2005) describes Wisconsinan glacial deposits in detail for the Hillsgrove quadrangle. Glaciers covered the entire area, moving in a south-southwest direction, with a recent maximum about 24,000–28,000 years ago. Glaciers were more erosional where valleys were parallel to ice movement; till deposits are typically thicker where ice cut across obliquely-oriented valleys (Braun, 2005). Thus, till deposits vary substantially in thickness up to 100 feet in Sullivan County (Reese and others, 2014). As the glaciers melted, outwash deposits flooded the valleys. Later, streams added alluvium over the outwash. Water-well records in the Hillsgrove area show a depth of 75 to 84 feet of unconsolidated materials.

Not limited to daylight hours, High Knob Overlook also provides scenic views of the heavens in clear weather. The vista is the most southeastern of Pennsylvania's prime star-gazing locations. The ChesMont Astronomical Society (CAS) lists the site as a dark-sky site, and provides a two-day, clear-sky forecast on its website (CAS, 2019).

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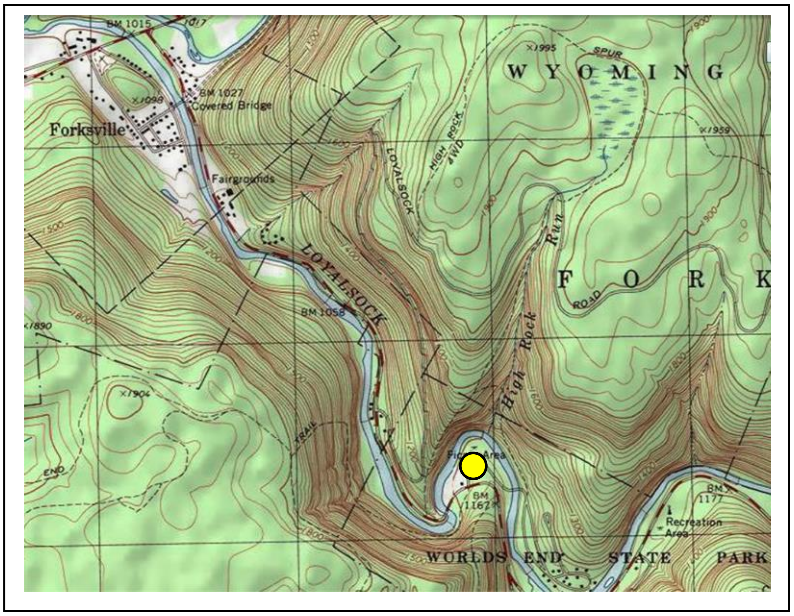
Stop 4. Lunch and the Huntley Mountain

Discussant: Bill Kochanov, (retired) Pennsylvania Geological Survey

The site is located approximately 1.75 miles southeast of the town of Forksville, Susquehanna County, along SR 154.

Coordinates: 41.471092°, -76.583448° (Figure 4.1).



This site was visited during the 2006 Field Conference. As such, we will pick up where they left off, a full belly from a fine lunch and enjoying the aesthetics along the banks of the Loyalsock Creek…

Figure 4.1. Location map for Stop 4, Worlds End State Park. North is up.

Introduction

The stop leader, Duane Braun, began with a brief history of the park and segued into its geomorphic and glacial story amid the backdrop of the Loyalsock gorge. Attendees are referred to the FC proceedings for additional reading on this stop (Braun, 2006, p. 84-85.)

The primary gist of the stop was lunch and to ponder a stratigraphic dilemma, that of placing the local redbeds within the Devonian Upper Catskill Formation or within the Lower Huntley Mountain Formation, a pesky transitional stratigraphic unit that tends to play on both sides of the Devonian – Mississippian fence.

Discussion

As geologic maps go (Berg, 1981), the Huntley Mountain at Forksville (Figure 4.1) is approximately 600 feet thick with the lunch stop at Worlds End being about 300 feet below the base of the Mississippian Burgoon Formation (Pocono Formation to all you easterners). Having walked much of the Loyalsock Creek and its tributaries locally as part of a surficial geologic mapping project, Braun (2006) observed that redbeds continued from the lunch stop downstream as well as down stratigraphic section. Although there are redbeds at the base of the outcrop across the Loyalsock, a better outcrop is exposed approximately 1.1 miles west of the lunch stop along the north side of SR 154. Berg and Edmunds (1979, p. 53-54) reference this very outcrop (Figure 4.2) and include it as part of the Huntley Mountain The outcrop is also known for preserved aestivation burrows (Figure 4.3).

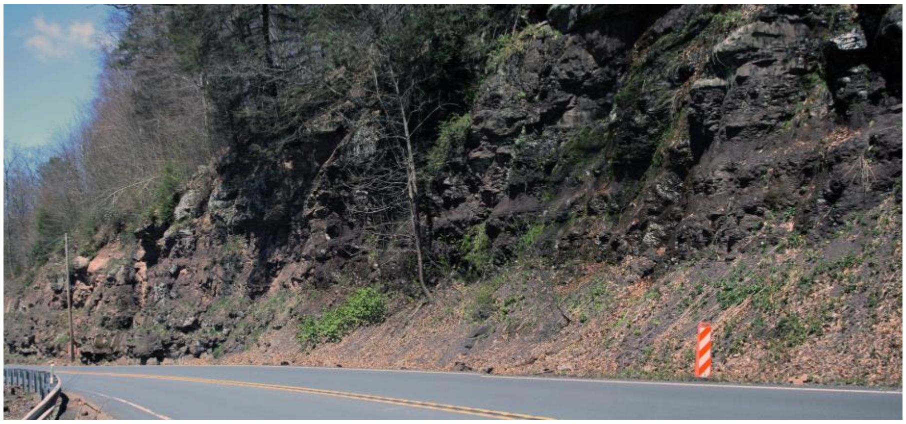


Figure 4.2. Redbeds in outcrop of Huntley Mountain along SR 154.

Figure 4.3. Fossil aestivation burrows from Huntley Mountain outcrop along SR 154. Hammer head length 18 cm.

Why the fuss about redbeds? Redbeds have long been synonymous with the Catskill so one would think that if one finds them in outcrop, there is a good chance they may be Catskill. Berg and Edmunds (1979) summarized that approximately five percent of the Huntley Mountain Formation, at the type section, are what have been loosely termed as "red beds" and that there are very few exposures at the type section due to their fine-grained nature and erodibility. Braun (2006) noted from the measured lithologic description of the Huntley Mountain (Berg and Edmunds, 1979, p. 65-74) that it contains a lot of covered intervals - Kochanov estimates about 66 meters or 39 percent. It would seem plausible that the more easily eroded, finer-grained lithologies could be buried in these covered intervals.

From a lithologic perspective, the Huntley Mountain is very similar to the underlying Catskill, save one marker bed, the Cedar Run conglomerate.

The Cedar Run is a unique marker bed within the Huntley Mountain in that it is a quartz (mostly) pebble conglomerate with marine fossils. In reading the lithologic descriptions it seems that there is a dichotomy of sorts. The lithologies described below this bed change character, becoming more, well-defined, fining upward cycles - the presence of intraformational conglomerates as the basal component of those cycles, grading upwards into low angle, trough cross-bedded, olive gray, medium-grained sandstones, transitioning into planar bedded sandstones, and continuing upwards into a variety of finer-grained lithotypes ranging in colors from olive gray to reddish gray.

Another point of note coming from the measured section, is the presence of plant fossils above and below the Cedar Run. Below the Cedar Run, they identified, with some question, the plant fossil *?Archaeopteris* (Figures 27, p. 49 and Figure 28, p.50) and a more definitive identification of *Adiantites cf. A. spectabilius* (Figure 26, p. 48) found above the Cedar Run along with *Lepidodendropsis. Adiantites* and *Lepidodendropsis* have been assigned a Mississippian age (Read, 1955). Based on this, one could possibly use the Cedar Run as a Mississippian/Devonian dividing line. Pulling back, one also has to consider that this is only one data point, and as a marker bed, the Cedar Run is not ubiquitous.

Archaeopteris tends to fall more on the Devonian side. Although some arguments give *Archaeopteris* a much longer range in PA (Pettitt and Beck, 1968). Berg and Edmunds equate the presence of “Rhacopteris” latifolia to a similar occurrence from the Horseshoe Curve area near Altoona (Read, 1955) which was reported from the Lower Pocono (Mississippian) not Catskill. Also from the Huntley Mountain type section was the form genus *Callixylon*, which is basically the stems of *Archaeopteris*. While this may be correct, the reader should be aware that individual stem parts do not necessarily mean they belong a specific genus of plant fossil.

The ?*Syringothyris* of Figure 29 (Berg and Edmunds, 1979) possibly ?*Tylothyris sp.*, a brachiopod genus ranging in age from the Lower Middle Devonian to the end of the Middle Mississippian. This brings up the issue of a marine fossil in a “terrestrial” setting. Colton (1963) explains that the Cedar Run conglomerate marks a rapid marine transgression separating the Mississippian and Devonian. Was it a transgression or was it perhaps reworking of previously deposited fossil material? It was reported that spiriferid brachiopods were rare and “not well preserved” (Berg and Edmunds, 1979). Would a transgressive event be that poorly represented by so few fossils?

So, what defines the Huntley Mountain? Apparently, it was not based on the presence or absence of plant and invertebrate fossils. Was it the presence or absence of redbeds? In his mapping of the Cedar Run quadrangle, Colton (1963) uses the highest occurrence of red sandstone as the end of the Catskill. Reddish gray sandstones have not been observed in the Huntley Mountain (Berg and Edmunds, 1979). There is the Cedar Run conglomerate and that seems to be the defining moment. More of this discussion at tomorrow when we explore the Huntley Mountain stratigraphic equivalent, the Spechty Kopf Formation.

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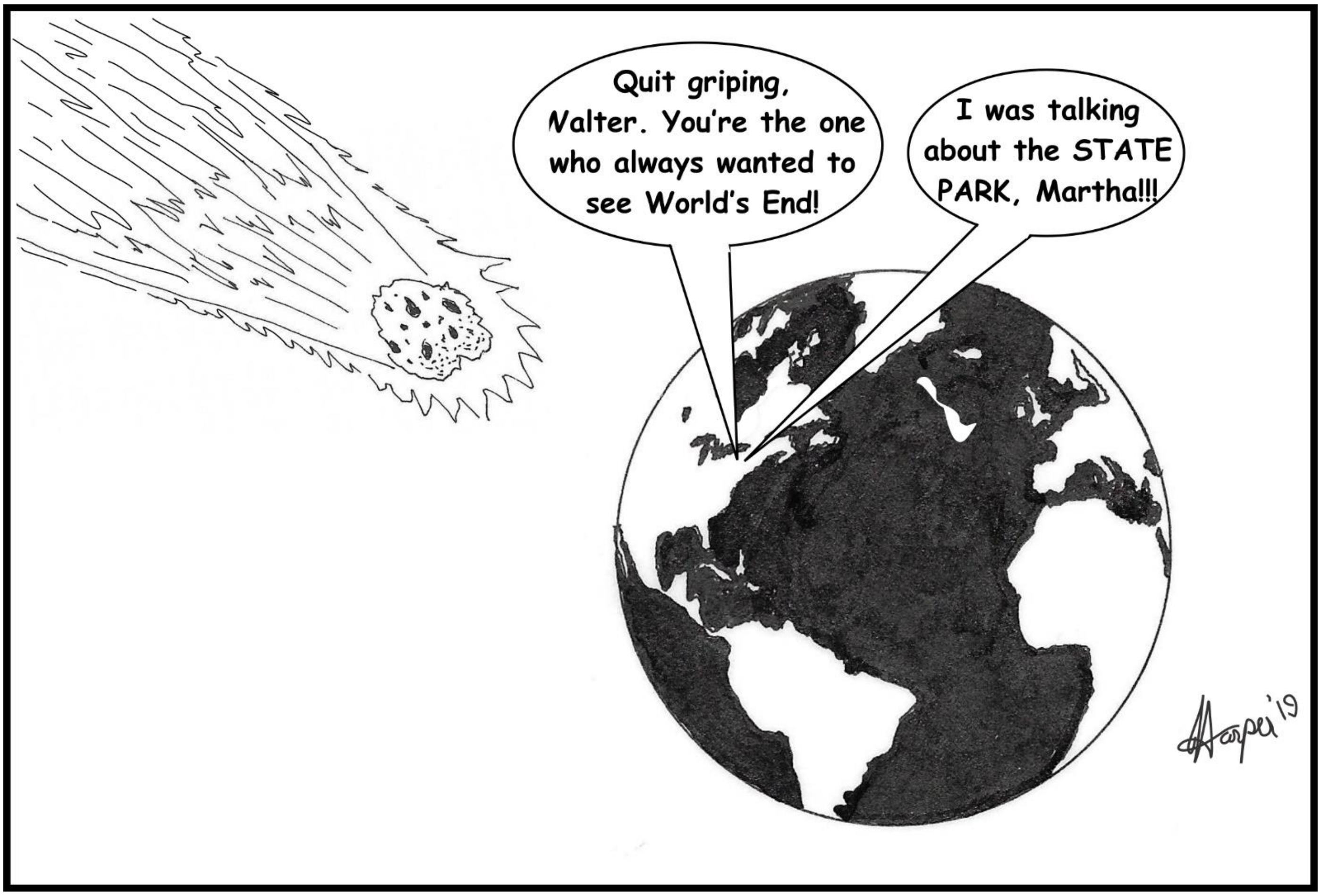

Stop 5. Steep Dipping Catskill Formation, Little Loyalsock Creek

Discussant: Brett McLaurin, Bloomsburg University

Authors: Brett McLaurin, S. Christopher Whisner and James Adams
Department of Environmental, Geographical and Geological Sciences, Bloomsburg University

The site is located on PA Highway 87 along Little Loyalsock Creek (Figure 5.1).
Coordinates: 41.505511, -76.565054

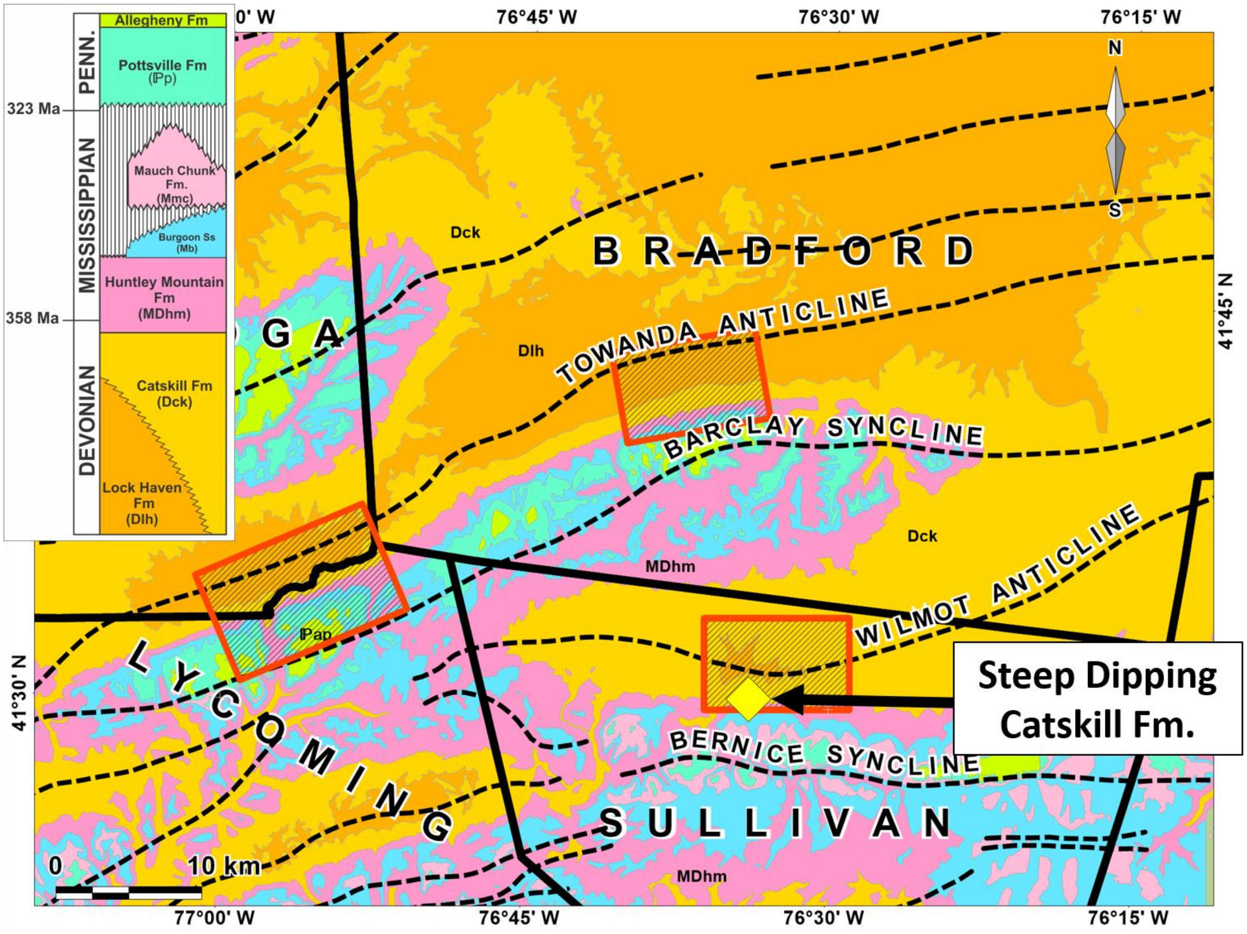

Figure 5.1. Geologic map of the Appalachian Plateau Province in northern Pennsylvania, denoting the area of deformation with regional geology and principal geologic features. Geology from Berg et al. (1980). Fold axis location modified from Faill (2011). Stratigraphic chart modified from Berg (1993).

Key Points

1) Zone of steeper dips in the Catskill Formation
2) Asymmetrical Wilmot Anticline with steeper dipping south limb
3) Zone ~9 km along strike (roughly east-west)
4) Dips to the south-southwest as much as 40 degrees
5) Interpreted to occur in zones where subsurface Salina Salt is thicker

Introduction

Within the Appalachian Plateau, strike-parallel zones of more extensive deformation occur within Devonian strata. Appalachian Plateau structures consist of broad anticline and syncline with bedding dips in the 3 to 6° range (Figure 5.1). Field mapping in areas of Sullivan and Lycoming counties have identified zones where structural dips often exceed 30 degrees (Figure 5.2). These areas are on the south limbs of the south-southwest verging, asymmetrical Towanda and Wilmot anticlines and are largely confined to strata of the Devonian Catskill Formation. Deformation extends along strike 8 – 20 km and are 2 – 3 km wide. There is often a topographic expression of the folding that is evident on digital elevation models and the increased structural dip has caused localized slope stability problems (Figure 5.3).

Figure 5.3. Roadcut of Catskill Formation along PA Route 87. Picture is facing west. Catskill sandstone and shale dipping 35°

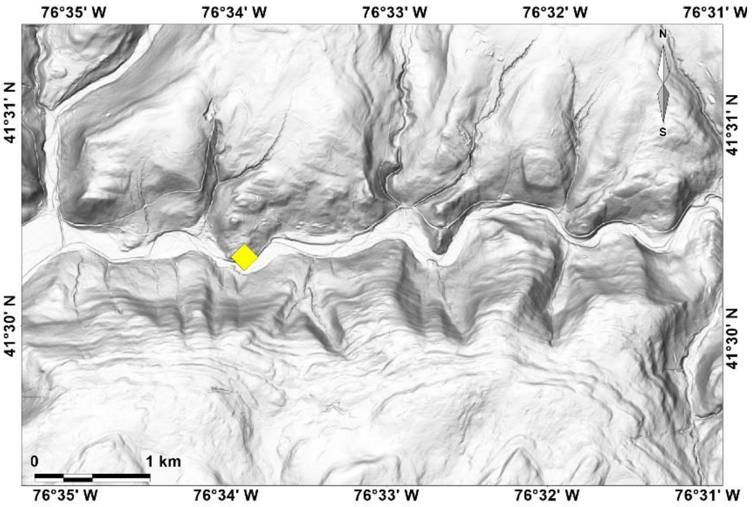

Figure 5.3: LIDAR image of stop area along Little Loyalsock Creek.

Location and Geological Setting

Anticlines and synclines in the Appalachian Plateau Province exhibit wavelengths of 8 – 32 km with structural relief up to 760 m (Wiltschko and Chapple, 1977). Dips are generally shallow, ranging from 3 to 6°, though areas of steeper dips have been previously noted (Beardsley et al., 1999). The mechanism for the broad, gentle folding is attributed to a décollement within the Silurian-age Salina Salt that lies approximately 2 km below the surface (Gwinn, 1964; Frey, 1973; Wiltschko and Chapple, 1977). As a result of regional compression associated with the Allegheny orogeny (Mount, 2014) the synclines formed by salt withdrawal and the accumulation of salt formed anticlines (Frey, 1973; Harrison et al., 2004). Early workers observed that the anticlines within the plateau province are asymmetrical with steeper-dipping southern limbs compared to the northern limbs of folds (Rogers, 1858; Kindle, 1904; Sherrill, 1934). This has led to debate over the direction of compression and whether it originated from the southeast or via gravity sliding from the north-northwest (Gwinn, 1964; Frey, 1973; Mount, 2014).

Seismic reflection data presented by Frey (1973) (Figure 5.4) show an asymmetrical, salt-cored, Wilmot anticline with a steeper dipping south flank. The subsurface faults are inferred based on the offset of reflectors that represent the top of the Tully Limestone (late Middle Devonian) and the Onondaga Limestone (early Middle Devonian). However, Gillespie et al. (2015) argue that the steeply dipping faults that are interpreted from seismic data are kink-band folds and the only faults involved in these structures are low angle thrust faults.

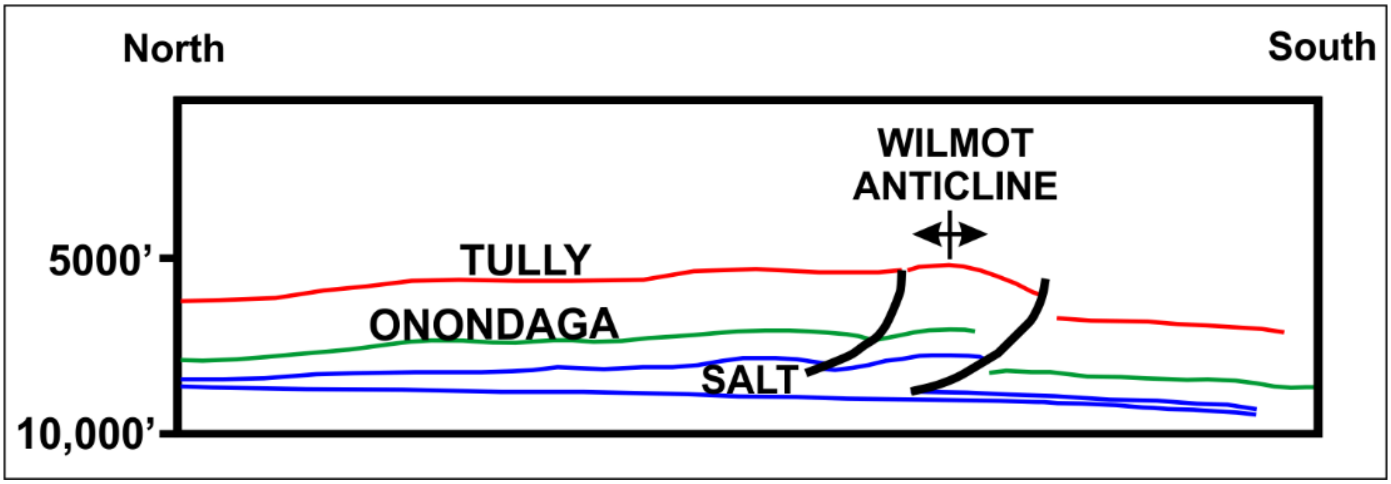

Figure 5.4. Seismic line modified from Frey (1973). The interpreted line shows the position of the Salina Salt along with the top of the Onondaga Limestone (early Middle Devonian) and the Tully Limestone (late Middle Devonian). Note the steeper dipping, south limb of the Wilmot anticline, compared to the fold's north limb.

Geologic Mapping

Most of the field research has focused in northwestern Sullivan County along the east-west trending Little Loyalsock Creek which is bounded to the south by the Bernice syncline and to the north by the Wilmot anticline. Here, strata on the southern limb of the Wilmot anticline exhibit a trend of shallow dips (7-8 °) closer to the fold axis that increase in magnitude to the south. Structural dips in the most intensely deformed areas are 17 to 40 ° to the south-southwest, with minor low-angle faulting present (Figure 5.5). Although the Huntley Mountain Formation, south of Little Loyalsock Creek, wasn't examined along the northern slope, LIDAR data indicate that the dip magnitudes are the more typical 3 to 6°.

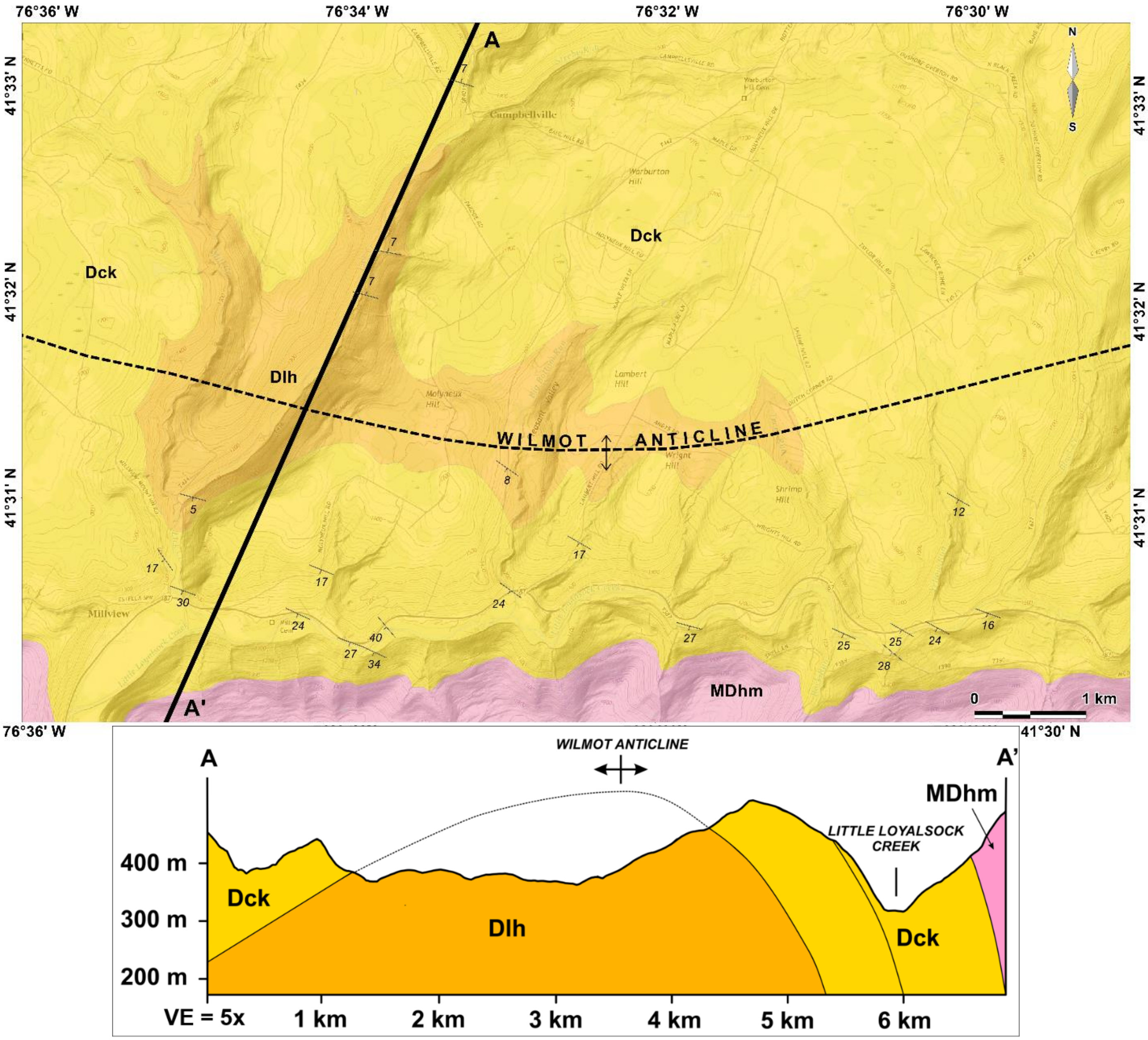

Figure 5.5. Geologic map and cross section of part of the Overton 7.5' quadrangle. Note the shallow dips closer to the fold axis and the increasing dip magnitudes farther south. Bedrock geology from Berg et al. (1980) and Faill (2011).

Discussion

We hypothesize that these zones of more steeply dipping strata are likely associated with regions where the Silurian-age Salina Group salt in the subsurface (~2.5 km depth) is thicker and may exceed ~850 m (Mount, 2014) (Figure 5.6). The thicker accumulations of salt, forming the cores of the anticlines, could influence regional structure in the shallower surface exposures resulting in steeper dip magnitudes. Areas where the salt is thinner in the subsurface would result in more typical dip magnitudes of 3 to 6 °.

We have identified additional areas in northern Pennsylvania where steeper dips are observed. There is an extensive zone along the southern limb of the Towanda anticline in northern Lycoming and southern

Bradford counties. Here, dips approaching vertical are noted in both the Catskill and underlying Lock Haven Formation. These areas of steeper dips also correspond to where Mount (2014) identified thicker subsurface salt.

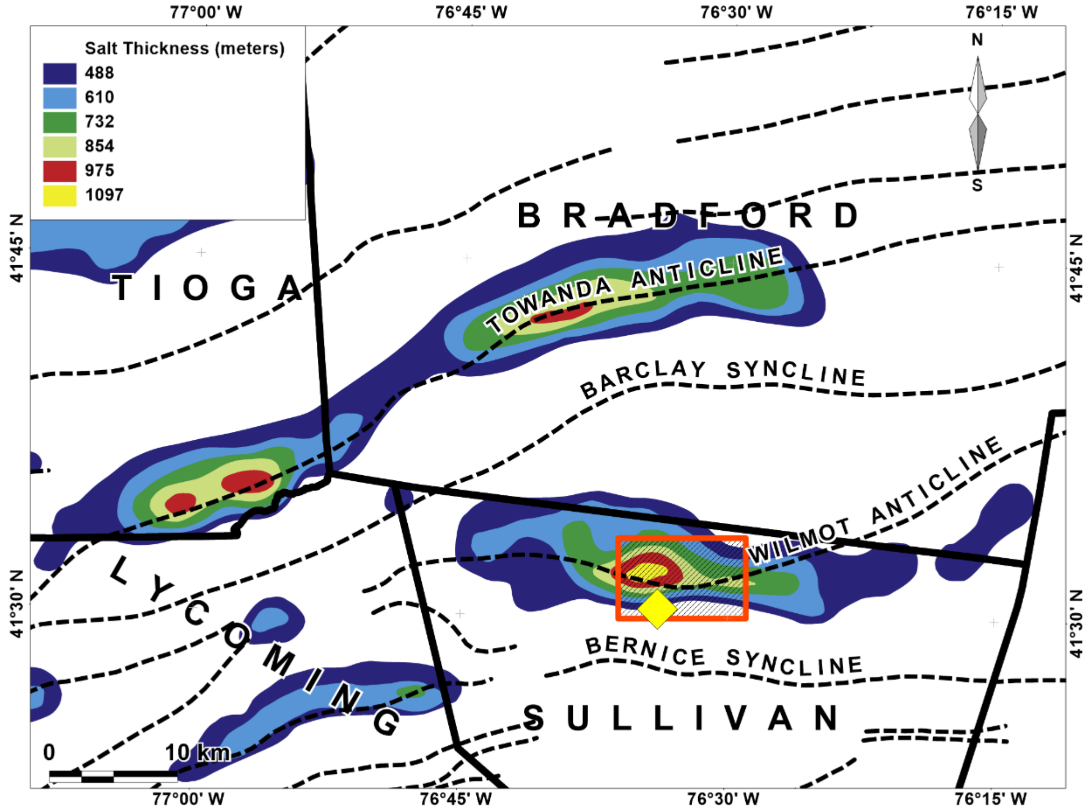

Figure 5.6. Thickness of the Salina Salt in the subsurface, modified from Mount (2014).

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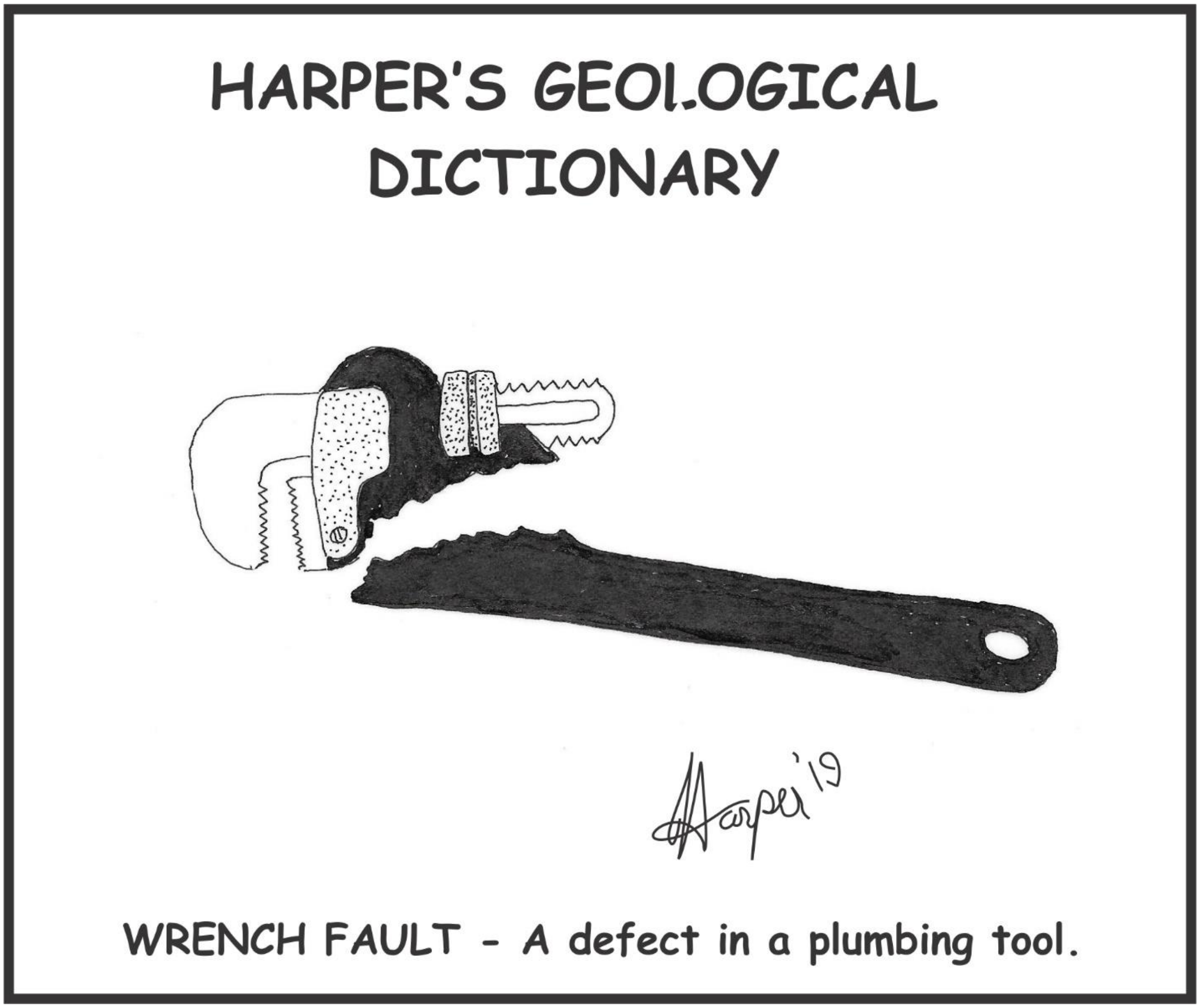

Stop 6. "Haystacks" Interval at Dutchman Falls, Loyalsock Creek

Discussant: Brett McLaurin, Bloomsburg University

Authors: Brett McLaurin, Ashley Barebo, Taylor Himmelberger, Leah Topping and S. Christopher Whisner
Department of Environmental, Geographical and Geological Sciences, Bloomsburg University

The site is located on the Loyalsock Trail along the Loyalsock Creek at Dutchman Falls
Coordinates: 41.449972°, -76.452156° (Figure 6.1)

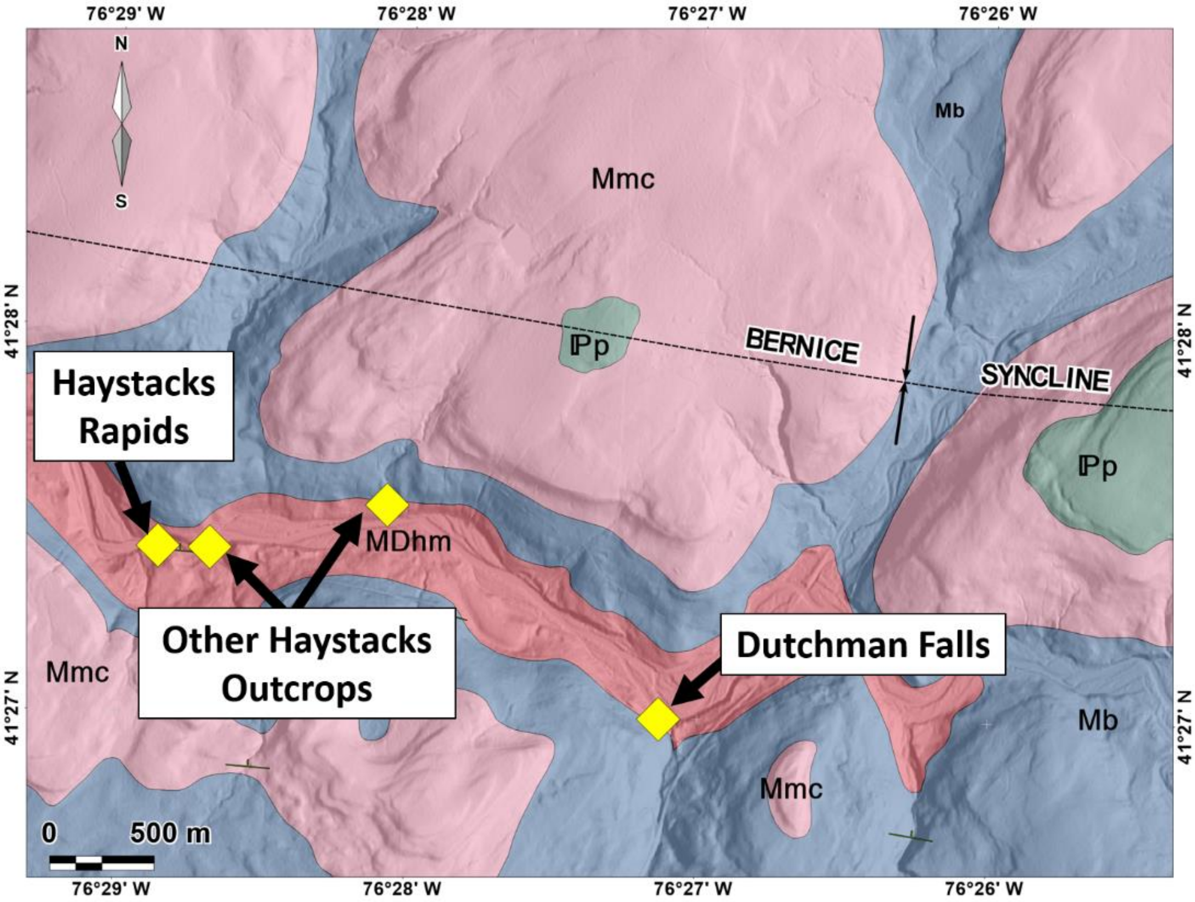

Figure 6.1. Portion of geologic map of the Laporte 7.5' quadrangle showing location of the Haystacks outcrop at Dutchman Falls, relative to other Haystacks exposures along Loyalsock Creek.

Key Points

1) Discontinuous regional marker "horizon" of orthoquartzite/silica-cemented sandstone, approximately 1.5 m thick
2) Upper Huntley Mountain Formation (Devonian – Mississippian).
3) Distinctive lithology, massive, and resistant to erosion.
4) Higher %SiO_2 content and lower %Al_2O_3, %Fe_2O_3, %MgO, and %K_2O compared to other Devonian – Mississippian sandstones in the Appalachian Plateau.
5) Represents a silcrete formed from groundwater processes.

Introduction

Figure 6.3. Aerial image of the Haystacks at Haystacks Rapids along Loyalsock Creek.

Figure 6.3. Outcrop photograph of the Haystacks interval at Dutchman Falls.

The "Haystacks" interval was first described along Loyalsock Creek, approximately 2.5 km to the west of this field trip stop (Figure 6.2). There, the highly resistant, orthoquartzite/silica-cemented sandstone of the Huntley Mountain Formation results in a series of rapids. The distinctive nature of the interval compared to the bounding stratigraphic succession has generated substantial interest in deciphering its origin (Gillmeister and Springer, 1993; Hill, 2007; Hill, 2008; Hill and Jimenez, 2010). Work by Woodrow (2006) and Gillmeister and Hill (2006) was a focus of the 71st Annual Field Conference of Pennsylvania Geologists. It has been recognized as far east as Rickett's Glen State Park (Columbia County) and to the west in the vicinity of Picture Rocks, PA (Lycoming County). It's distinctive appearance and highly resistant nature suggests its potential significance as a stratigraphic marker. Interpretations of the Haystacks origin has varied from paleoseismite deposits to ejecta associated with a bolide impact. Here at Dutchman Falls, we revisit the Haystacks for additional discussion of its possible origin (Figure 6.3).

Petrology

The petrographic characteristics of the Haystacks were documented in earlier studies (Gillmeister and Springer, 1993; Hill, 2007; Hill, 2008; Hill and Jimenez, 2010). The distinctive appearance of the Haystacks relative to the Huntley Mountain Formation not only applies to outcrop, but also at the microscopic scale. The Huntley Mountain Formation has higher concentrations of clay minerals, muscovite, and polycrystalline quartz with grains showing slightly more angularity. The Haystacks is much cleaner, compositionally, and is dominated by monocrystalline quartz (Figure 6.4). One clear difference is in the nature of the rock fabric.

The Huntley Mountain Formation is grain-supported, whereas the Haystacks is matrix-supported with grains separated by microcrystalline to cryptocrystalline quartz.

Geochemistry

Previous work on the Haystacks has focused on the distribution and petrology of the interval. Expanding on these efforts, two samples of the Haystacks were submitted to ALS for ICP-MS analysis. Results indicate that %SiO_2 was greater than 98% for both samples, with minor concentrations of %Al_2O_3 (1.0 – 1.2%), %Fe_2O_3 (0.4 – 0.5%), %MgO (0.02%), and %K_2O (0.22 – 0.27%). Comparisons with ICP-MS analyses on other sandstones from the Devonian – Mississippian demonstrates the geochemical distinctiveness of the Haystacks (Figure 6.5).

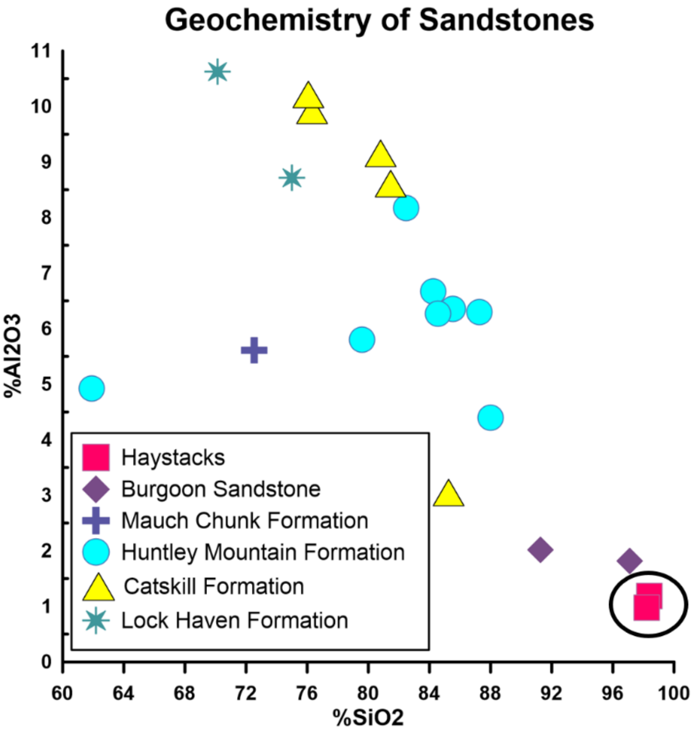

Figure 6.5. Plot of ICP-MS data from sandstones in the Appalachian Plateau compared with the Haystacks.

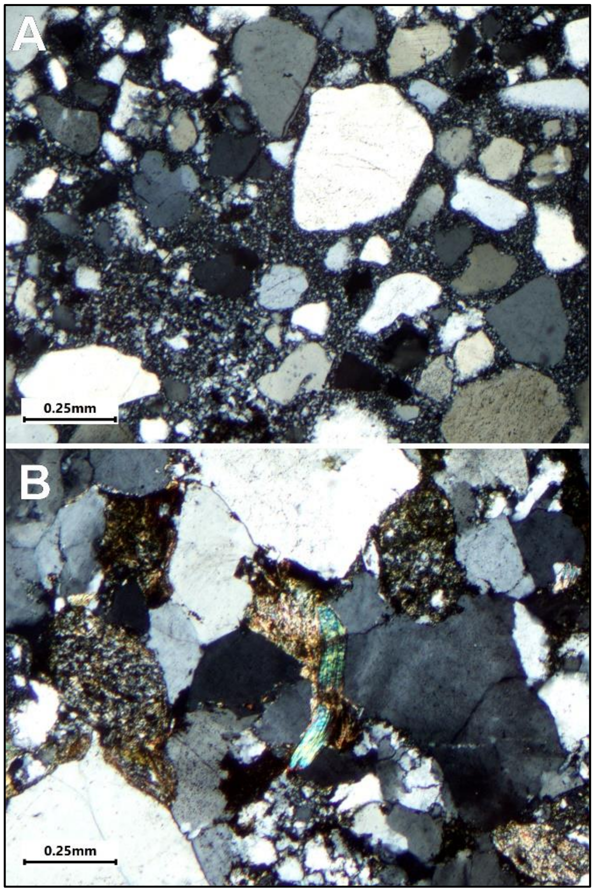

Figure 6.4. A) Photomicrograph of the Haystacks from Dutchman Falls. B) Photomicrograph of a sample of Huntley Mountain Formation taken several meters below the Haystacks.

Discussion

While previous interpretations of the Haystacks' origin have focused on extrabasinal controls, a review of the depositional context of the Huntley Mountain Formation may provide some alternative hypotheses. The Huntley Mountain Formation records deposition within low to moderate-sinuosity river systems that frequently avulsed across a broad alluvial plain. So, what sorts of intrabasinal or diagenetic processes within fluvial systems could result in an interval with the lithologic and geochemical characteristics of the Haystacks? The literature describing silica-cemented sandstones within fluvial successions considers such intervals a result of silcrete formation (Nash et al., 1998; Shaw and Nash, 1998; Ullyott et al., 1998; Ullyott and Nash, 2006; Nash and Ullyott, 2007; Ullyott and Nash, 2016). Silcretes, as originally defined, refers to gravel and/or sand, in which silica replaces and/or accumulates to form an indurated mass (Ullyott and Nash, 2006; Nash and Ullyott, 2007). Furthermore, they are considered a result of near-surface processes and can be attributed to both pedogenic and nonpedogenic origins (Ullyott et al., 1998; Ullyott and Nash, 2016). Comparison of the depositional environment, lithologic, petrologic and geochemical features of the Haystacks with documented silcretes shows several similarities. The discontinuous occurrence and massive appearance of the Haystacks along with its simple micromorphological fabric suggests a nonpedogenic silcrete origin. Also, the geochemical signature of the Haystacks has more in common with other documented silcretes (Figure 6.6) than it does with other stratigraphic intervals. The types of nonpedogenic silcretes include groundwater and drainage-line varieties (Ullyott et al., 1998; Ullyott and Nash, 2016). They form below the land surface and are related to the water table and/or groundwater flow. In settings where these silcretes are documented their geomorphological position is within or along the margins of the channel system (Figure 6.7).

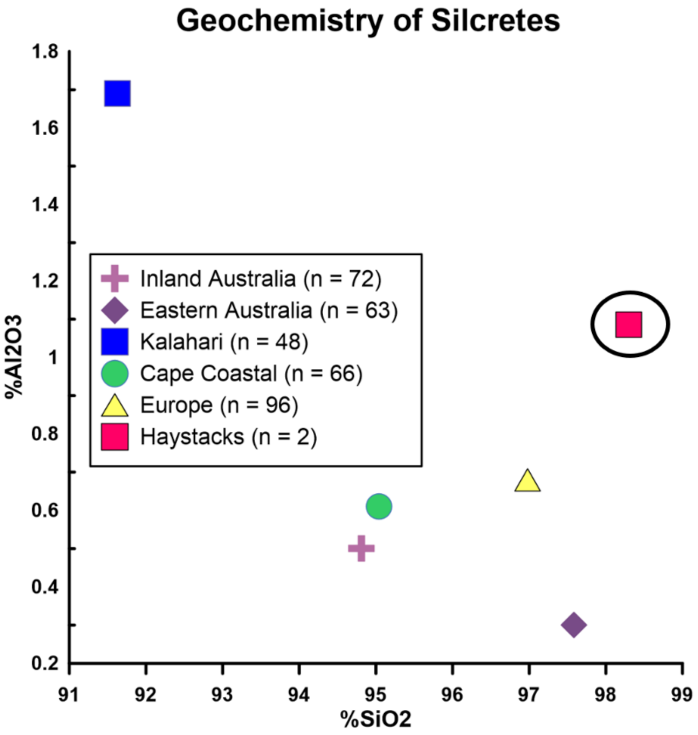

Figure 6.7. Plot of silcrete geochemistry compiled from Nash and Ullyott (2007) compared to the Haystacks. Note the higher concentrations of %SiO_2 and lower amounts of %Al_2O_3 relative to the sandstone geochemistry shown in Figure 6.5.

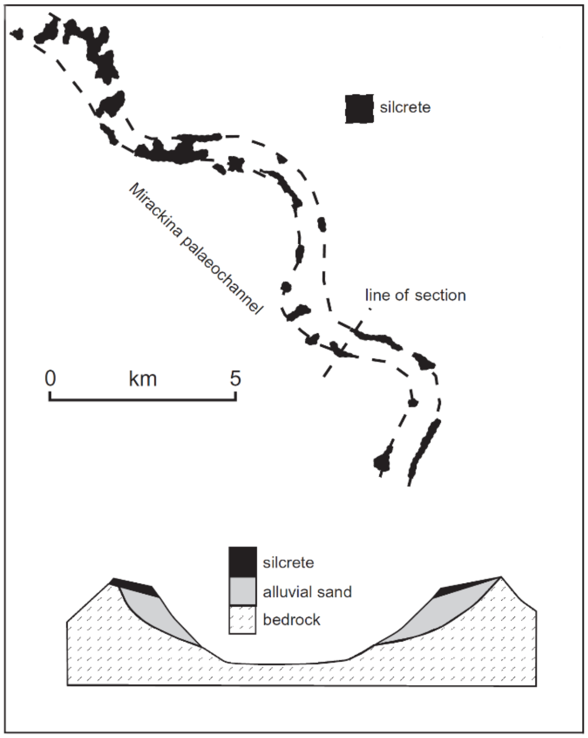

Figure 6.7. From Nash and Ullyott (2007). Distribution of silcrete along a Cretaceous paleochannel in Australia.

The process of silica precipitation can occur in a variety of paleoenvironmental conditions and the use of silcretes as an indicator of climatic conditions is disputed (Nash and Ullyott, 2007). The mineralogical distinction between the Haystacks and Huntley Mountain Formation may be a function of the influence of silica-rich acidic groundwater. More unstable mineralogical constituents, such as clay minerals, would have been leached and altered, resulting in a different mineralogical and geochemical composition. We recently identified siliceous sandstone like the Haystacks along channels exposed in the Cretaceous-age Cedar Mountain Formation near Green River, Utah. The patchy occurrence of these silcretes along the trace of the paleochannels is an excellent example of drainage-line silcretes. These bodies are up to 1 m thick and occur as discontinuous lenses. Their identification at differing elevations and stratigraphic levels indicates that they are not the product of a single event, but, rather, likely reflect multiple episodes of silicification, perhaps in response to a fluctuating water table. If the Haystacks formed under similar conditions as to what is observed in other locations with drainage-line and groundwater silcretes, then it is likely that the Haystacks represents a zone of silcrete formation at differing stratigraphic levels and not a discrete layer. However, even if the Haystacks is not a single bed and represents a zone of multiple silcretes forming at various times, then why aren't Haystack-like lithologies observed at other levels within the Huntley Mountain Formation? Also, why is the Haystacks confined to the Lycoming-Sullivan-Columbia county area? Mapping in the northern tier of Tioga County did not identify any Haystacks-type intervals.

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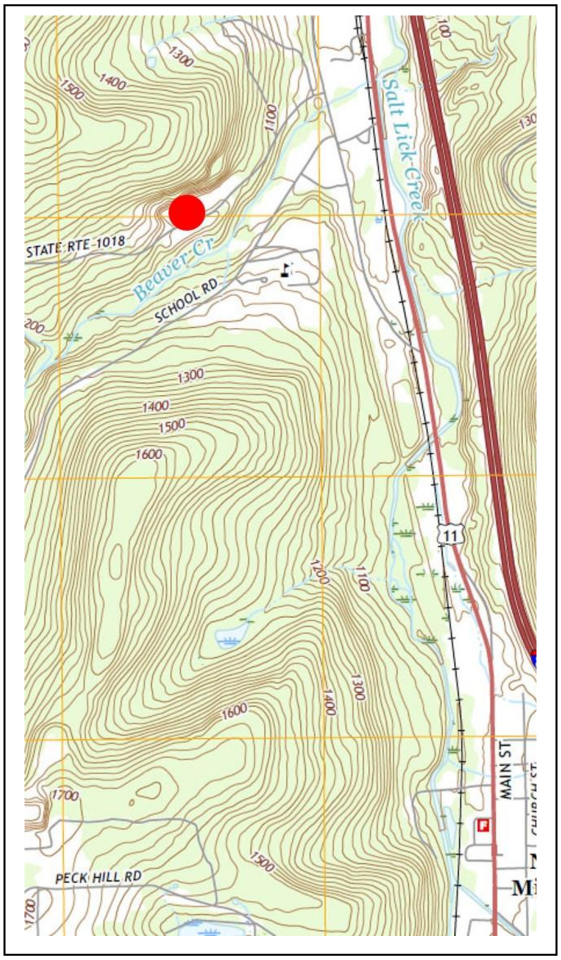
HARPER'S GEOLOGICAL DICTIONARY

PALEOLIMNOLOGY - The study of the leg bones of dinosaurs.

Stop 7. The H & K Quarry at New Milford: The Lock Haven and Catskill Formation contact

Discussant: Bill Kochanov, PAGS (Retired)

The site is located along SR 1018, approximately 1.7 miles northwest of the town of New Milford. Coordinates: 41.900290°, -75.742020° (Figure 7.1).



Although the quarry is not presently active, standard safety rules still apply - hard hats, steel toe/field boots, and safety vests are a must have. Do not go exploring beneath the highwall. Much of what you will see is quite visible from the open area in front of the highwall (although it may be a bit soggy in spots – you'll find out). There is a partly vegetated roadway along the west side of the quarry from which we can access different levels of contiguous outcrops without being beneath the highwall. There will be highly visible guards posted near the edges, don't mess with them. As stated yesterday, we are here at the courtesy of H&K and would like to continue being good, conscientious rockheads. Don't be a doot-dah-doot.

Figure 7.1. Location map for H&K New Milford Quarry. North is up.

Introduction

One of the long-standing forays into Upper Devonian stratigraphy in northeastern Pennsylvania has been the argumentative placement of the lower boundary of the Catskill Formation. Stevenson (1892, p. 1408) in his summary of the Catskill in northeastern Pennsylvania probably best defined the marine "Chemung" (Lock Haven Formation) and overlying nonmarine Catskill contact as,

> "… indeterminable, for the passage from one to the other is practically imperceptible at most localities; the line drawn at any locality, whether on stratigraphical or palaeontological grounds, is almost certain to be unsatisfactory at any other."

This appears to be the case over most of Wayne and Susquehanna counties, as the tug-of-war between the two in Devonian times left behind a legacy of largely transitional marginal marine to deltaic facies in Susquehanna County and more alluvial lithologies in Wayne County. The contact between the Catskill and Lock Haven Formations falls into several camps of thought for geologists in the field. Should the presence, or absence, of marine invertebrate fossils determine the line of demarcation, or should the presence of Catskill-type red beds set the standard, or perhaps some other criteria as a standard? This stop is typical for strata near this dividing line throughout much of northeastern Pennsylvania.

The Rocks

For reference, there are several points of focus. The graffiti bench, the Lock Haven pebbly limestone - up the road at the west end, and the clam dig at the east end of the quarry floor (Figure 7.2).

Figure 7.2. Points of note at the H&K New Milford Quarry. A. the graffiti bench, B. The pebbly limestone beds, and C. the clam dig. Note the redbeds atop the graffiti bench. Photo was taken with a Mavic 2 Zoom drone guided by Craig Ebersole (PAGS). View is north.

Facing the highwall (north), there is an obvious lithologic change at the level of the graffiti wall. The rocks atop the graffiti bench consist of redbeds (Catskill), those below contain no redbeds (Lock Haven).

Starting at the base of the quarry, the rocks of the Lock Haven are a mix of alternating beds of greenish-gray to dark-greenish gray siltstone, silty to fine sandy claystone/shale and brownish gray claystone and shale interbedded with fine- to medium-grained, medium- gray, near-horizontal planar and low-angle trough cross-bedded sandstones (Figure 7.3). The planar-bedded sandstones are often separated further by parting lineations ranging from 2-10 cm in thickness (Figure 7.4).

Figure 7.3. Near horizontal and low-angle trough cross-bedded sandstones within the Lock Haven Formation. Yellow bar is 2 m.

Figure 7.4. Parting lineations in Lock Haven sandstone. Blue shaft of hammer is 15 cm.

The Lock Haven throughout northeastern Pennsylvania is largely non-calcareous. It is much the case here. However, in the west end of the quarry, there are beds composed of a poorly sorted collection of sub-rounded to rounded calcareous and non-calcareous pebbles set in a calcareous sandy matrix. Cross-sectional views of slabbed samples show some pebbles being composed of concentric ring structures surrounding a rounded or oval nucleus (pisoids), others not (Figure 7.5). Both matrix and pebbles reacted positive to hydrochloric acid, enough to classify this bed as limestone (> 50 percent calcite).

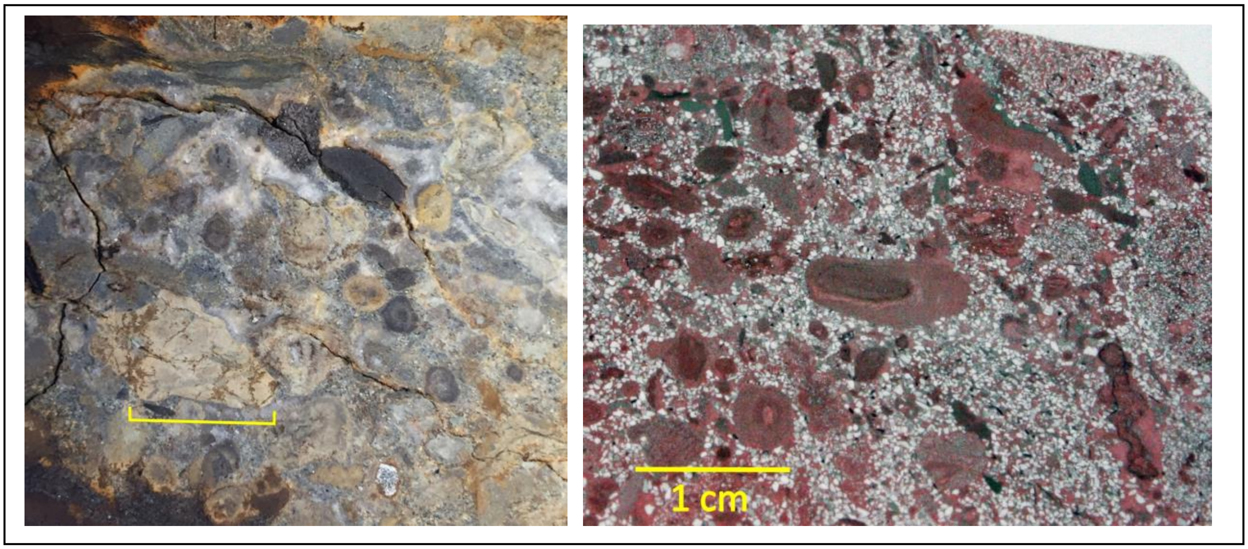


Figure 7.5. Left, slabbed section of pisolitic limestone from the H&K New Milford quarry. Yellow bar is 1 cm; right, thin section of agglomerate stained with alizarin red dye, red denoting calcite, white grains are quartz. Note concentric ringed pebbles in each image. Buff-colored clasts in left image are possible caliche.

Invertebrate and vertebrate fossils are very rare. No coquinite beds were identified. At the clam dig, at the east end of the quarry, indeterminate plant fossil fragments occur along with several species of bivalves in a brownish-gray shale (Figure 7.6). Fragments and very rare single-valve casts of a spiriferid brachiopod (possibly *Tylothyris sp*.) were found within the pebbly (pisolitic) limestone beds at the west end of the quarry (Figure 7.6). Trace fossils seemed to enjoy the silty/sandy shale just below the “graffiti bench” and can be assigned to the genus *Planolites* (Figure 7.6).

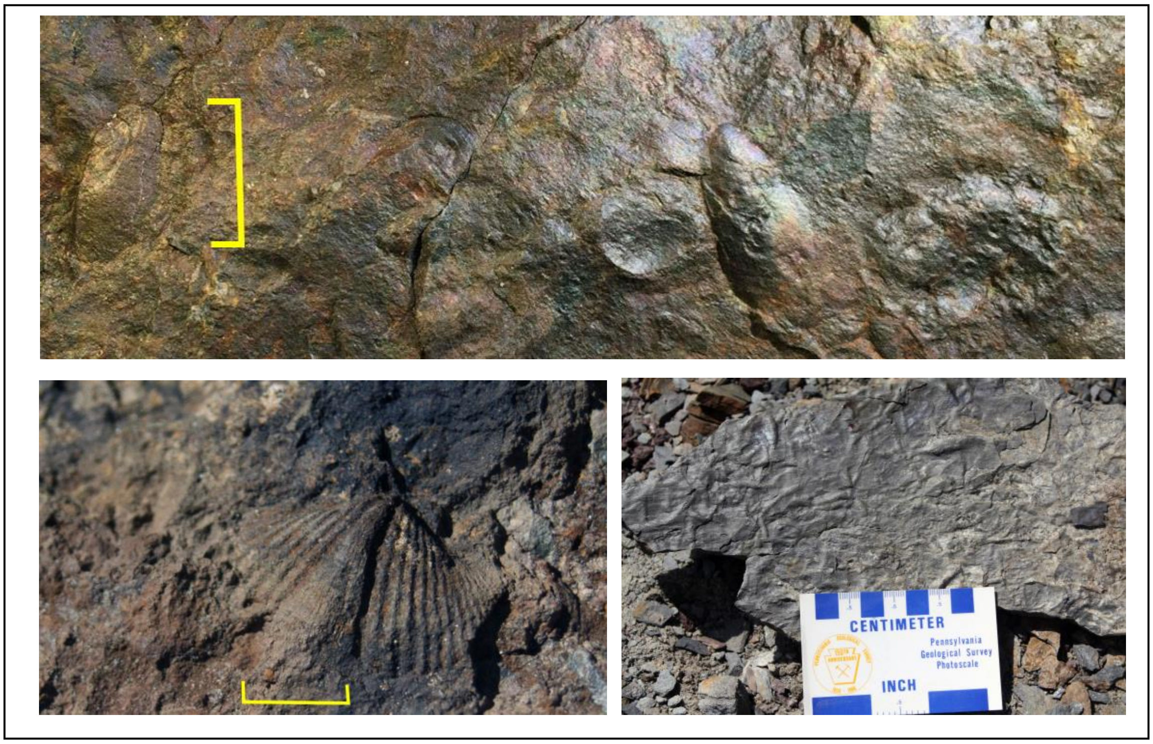


Figure 7.6. Invertebrate fossils. Top, bivalves; bottom left, spiriferid brachiopod *?Tylothyris*; bottom right trace fossil *Planolites.* Yellow bars are 1 cm.

The sandstones exposed on the graffiti bench grade upward into a redbed sequence of stacked fining-upward cycles (Figure 7.7). The base of the cycles begins with the benched greenish-gray, medium-grained sandstones that grade upward into reddish-gray, fine-grained sandstones through silty shales to silty mudstones. In some instances, the reddish-gray mudstones are capped by a greenish-gray layer indicative of the A soil horizon of a paleosol. Thin beds and laminae of greenish-gray sandstone oftentimes intervene, interrupting one cycle and delaying the onset of another new cycle. Incomplete fining-upward cycles are common.

Figure 7.7. Fining upward sets of redbeds. Left, graffiti bench sandstone grading upward into redbeds; right, close-up view, note paleosol cap of greenish-gray mudstone.

Among the redbeds up top, branching and "hairy" plant roots possibly mixed with crawling and burrowing traces. One other rope-like feature was also present that could be either a root or burrow trace (Figure 7.8).

Figure 7.8. A. Fossil "hairy" roots and possible crawling traces. Note greenish-gray halo around root trace at top. The color may be the result of reducing chemical changes induced by anaerobic bacterial activity (see Retallack, 1988, p.5); B. branching root segments; and C. rope-like burrowing? trace.

Discussion

The lower Lock Haven exposure provides some clues as to the dynamics of sediment deposition and dispersal.

At the far east end of the quarry the basal rocks are silty to slightly silty laminated shales and claystone shales indicative of relatively low energy offshore waters, perhaps an interdistributary bay environment. As burrowers, the elongate bivalves probably found the muddy substrate easier to move through based on their shape. Accompanying fossil plant fragments preserved along bedding surfaces suggest they settled in relatively "quiet" waters, which is supportive of a low-energy interpretation.

The sharp basal contacts of the low angle trough cross-bedded sandstones indicate that the channels cut through the softer sediment pavement of the marine shallows. Other such cutoffs are visible across the highwall (Figure 7.9). The planar beds of sandstone are likely overbank or splay deposits.

One puzzling aspect are the pisolitic beds. What was their source and secondly, how do they fit into this nearshore marine sequence? From a size perspective, they fall outside of the range for ooliths (2 mm cutoff). That leaves them as either pisoids or oncolites. Pisoids, larger (pea size) and less regular in shape than ooliths, have the same concentric and/or radial internal structure. Oncolites are also in the family of concentrically laminated, calcareous sedimentary structures but unlike ooliths, are created by the repetitive layering of the gelatinous sheaths of blue-green algae (AGI Glossary of Geology, 4th Edition). Their size ranges upwards to 10 cm in diameter.

Figure 7.9. Erosional base of a Lock Haven sandstone that has cut through silty shales. Yellow bar is 2 m.

One possibility is that they are lacustrine in origin developing within lakes on the upper delta plain. These lakes are likely derivatives of crevasse splay or flooded meander plains. Microbialites occurring within the Great Salt Lake, and within the Eocene Green River Formation of Utah have similar concentric features (Figure 7.10).

Figure 7.10. Recent microbialites from the Great Salt Lake (left) bearing some resemblance to stromatolites, and from the Eocene Green River Formation (right). Yellow scale bars are 5 cm.

Figure 7.11. Septarian-like pebbles along with pisolites from the west end of the H&K quarry; yellow bar scale is 1 cm.

The pebbles may be pedogenic in origin, perhaps as regular layers of calcite precipitating around plant roots, but that is speculative. The cross-sectional view of the pisolitic rock (Figure 7.5) shows a variety of nuclei. The gray centers perhaps having more organic material present. The more buff colored nuclei show rounded to irregular shapes that appear to be micritic and have a higher argillaceous content that have a caliche/calcrete nodular look about them. Figure 7.11 shows one of the clasts having a fracture-filled interior something similar to septarian nodules. Some of the calcite appears to be secondary, perhaps filling void spaces developed through dissolution. (Note: the specimens were recently collected – 7/2019 and have not been prepped for thin sections so any inferences are reasonable speculations).

I.C. White (1881) felt that the separation between the Catskill and underlying marine “Chemung” (i.e., present day Lock Haven Formation) should be based on physical characteristics and favored separating them at the lowest Catskill red bed. In this instance, the presence of “redbed” lithologies were key to marking the Catskill boundary. Marine invertebrate fossils identified above such deposits, however, threw salt into the eyes of the interpreter and a marine Catskill member was born.

The argument over redbeds vs. fossils was carried into recent mapping projects in 2002 where brachiopods, crinoid columnals, and bivalves laid the foundation for McElroy (2002) and Inners (2002) creation of the Lower Catskill Great Bend and the Upper Catskill Lanesboro “Members.” Both “Members” were described as being lithologically similar, being differentiated only by the occurrence of marine fossils (Inners 2004).

The documentation of brachiopods within the Catskill in northeastern Pennsylvania is scant with no partial or complete specimens to re-examine or reports on their relative abundance. Shells are rare and, when found, are typically weathered, either as incomplete single valves or shell fragments. It is somewhat coincidental that Willard (1939, p. 295-297) also noted the scarcity of fossils and their poor preservation for his "New Milford formation." Further research is needed to determine if the New Milford formation is correlative with this exposure. He also noted that pelecypods dominated the fossil record (recall the clam dig).

The inarticulate brachiopod *Lingula* has been identified in the Franklin Forks quadrangle (abutting quadrangle to the north) by Kochanov (2002). *Lingula* has a street rep for being common to brackish environments, something one would expect to find in the Catskill-Lock Haven transition.

Crinoid columnals are another story. Their recognition within the Catskill has come under some scrutiny, in PAGS circles, as they tend to be very similar to paleo-pedogenic clasts occurring within intraformational conglomerates or "agglomerates." The agglomerate clasts and matrix are largely calcareous and to the uninitiated, the rounded clasts can bear morphological and chemical similarities to fossil specimens and be erroneously identified as crinoid columnals, particularly when weathered. The pisolitic pebbles observed in the New Milford quarry could also perform the same ruse of mistaking the pisolites for crinoid columnals. Examination of thin or polished sections would be very useful tools in this instance.

Mapping projects by Kochanov (2002) and McElroy (2002) identified six outcrop stations out of 192 with identifiable invertebrate fossils. That comes out to a whopping 4.6 percent for two quadrangles. Wildmann and Baluta (2002), Kochanov and Potter (2016a,b,c), Kochanov and Neboga (2017), and Behr (2017) recorded no occurrences of invertebrate fossils within the mapped Catskill. Catskill marine fossils apparently are present in the Susquehanna quadrangle (Inners, pers. comm. 2019; Inners, 2002) but the data were not available at this time for review. Bivalves were identified by Kochanov and Behr at the Stevens Point site in the Susquehanna quadrangle (see Inners, 2004) riding the Catskill/Lock Haven contact. In that respect are the bivalves marine, brackish, or freshwater types?

These fragmented occurrences pose an interesting question. In total, there were only a handful of sights that marine fossils were reported, and with that, there were some doubts as to fossil identification. This small pool of samples provides a rather limited statistical base on which to define a widespread marine unit. Do they constitute a transgressive (onlap) event or do these sporadic occurrences infer erosion and transport of clasts from a relict marine horizon? In considering the prograding Catskill sediments into a marine setting, several questions are raised as to what a transgressive unit would look like and would there be an accompanying diagnostic faunal community. The nearshore marine environment would be subjected to changes in sediment distribution patterns as well as changes in salinity, supporting those organisms that are more adaptive to those fluctuating variables. The communities should be there.

Recognizing a transgressive event is not always clear cut. For example, the Lafourche subdelta of the Mississippi River is actively being eroded, resulting in a localized "transgression" while active sedimentation is ongoing at the site of the modern birdsfoot delta (Kochanov, 1983, p.21). Such shifting and subsequent subsidence of active sedimentary depocenters could account for the preservation of marine beds outside the zone of active delta progradation being stockpiled for some later erosive event from the mainland. Just a thought.

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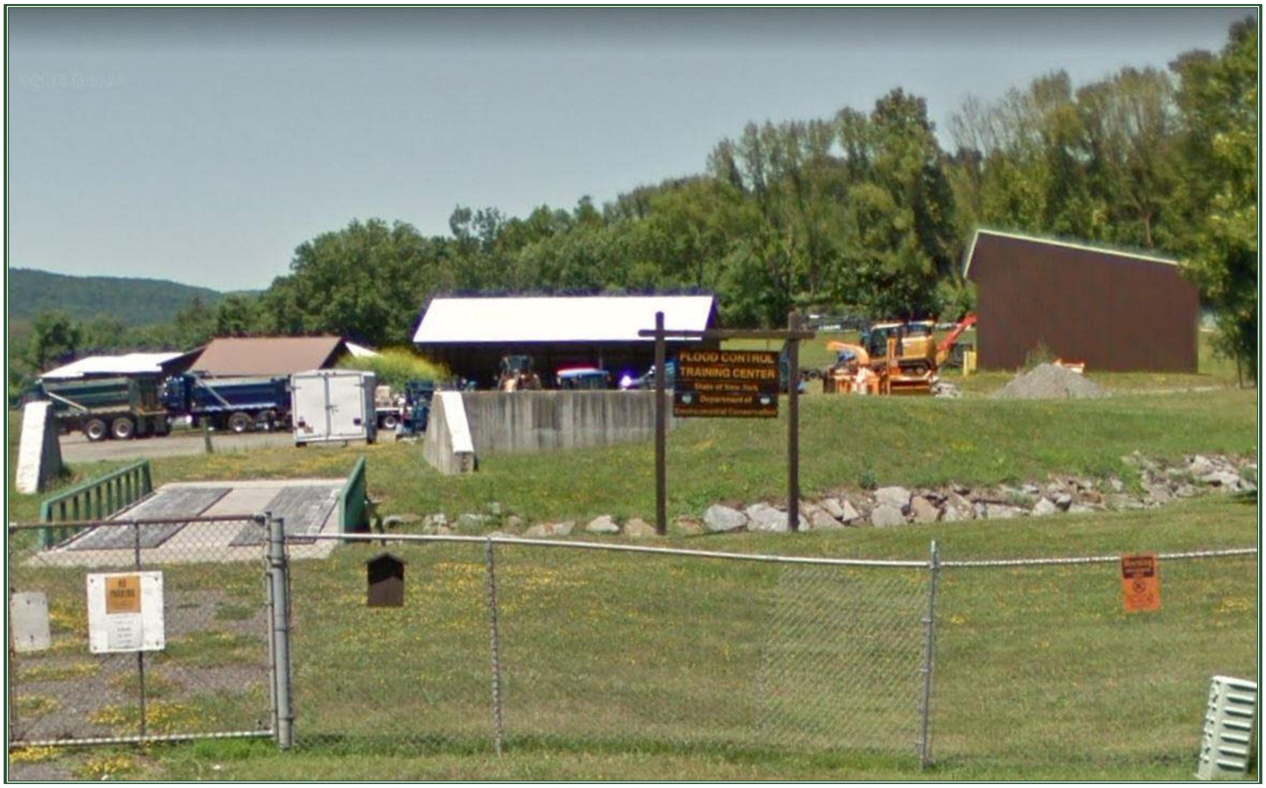
Stop 8. New York State Department of Environmental Conservation
Flood Protection and Dam Safety, Division of Water
Flood Control Training Center

Discussants:
Benjamin D. Girtain-Plowe, PE
Assistant Engineer (Environmental), Flood Protection and Dam Safety, Division of Water
and
Gary Priscott, P.G.
Professional Geologist 1, Division of Environmental Remediation

Coordinates: 42.041896, -75.796524

A brief presentation:

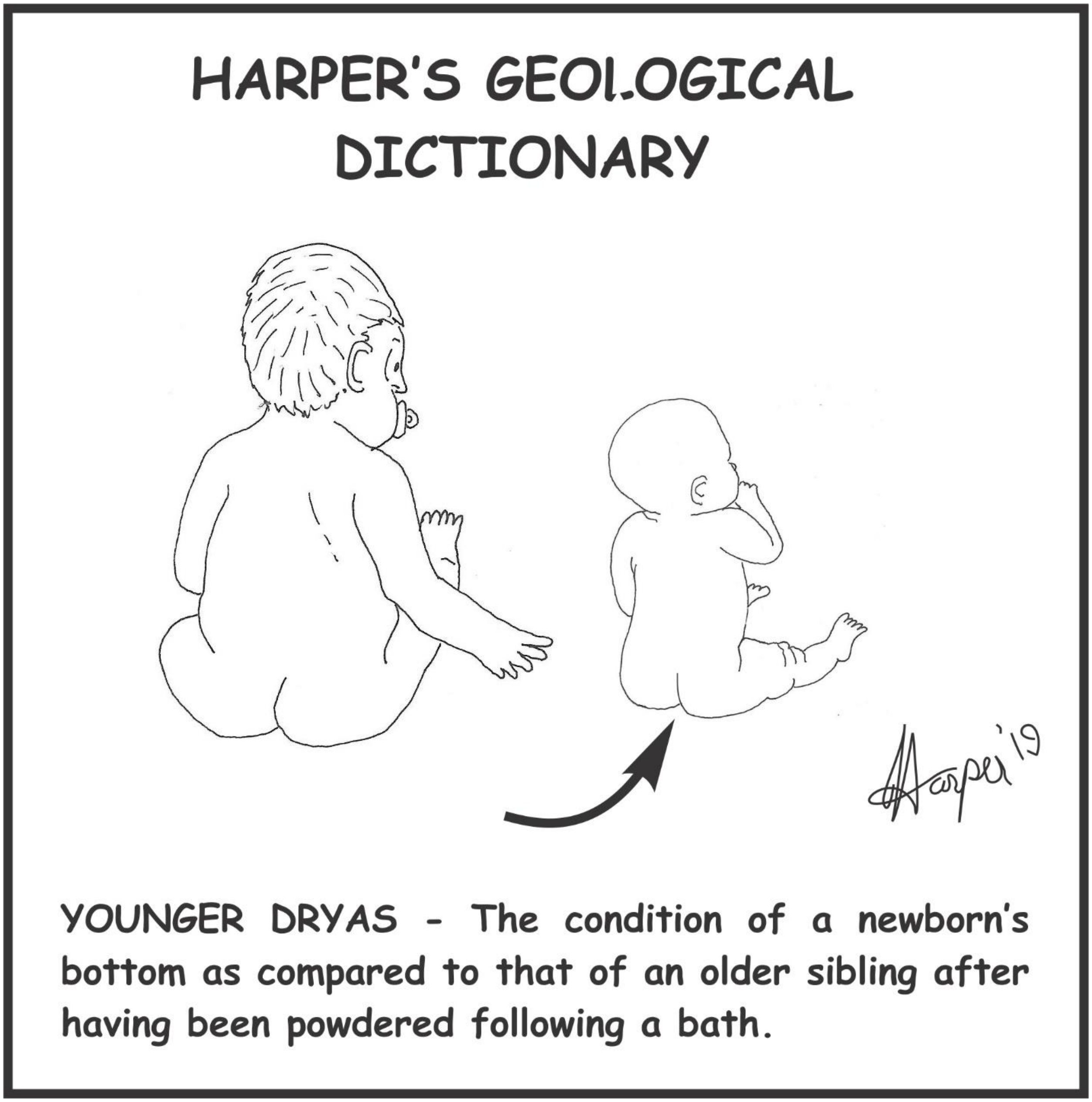
1) Safety moment slip trip fall
2) Intro/history flood protection and Kirkwood office training center, DEC region 7
3) Brief overview dam safety, floodplain management, & environmental remediation
4) local geology and experience as flood patroller
5) walk through of flood control training center – levee, closure, and drainage structure
6) conclusion and questions



New York State Department of Environmental Conservation
1679 US Route 11, Kirkwood, NY 13795-1602
P: (607) 775-2545x106 | C: (607) 592-2864 | F: (607) 775-2019 | benjamin.girtainplowe@dec.ny.gov

Stop 9. LUNCH – Veteran's Park

Coordinates: 42.038091, -75.802367



HARPER'S GEOLOGICAL DICTIONARY

YOUNGER DRYAS - The condition of a newborn's bottom as compared to that of an older sibling after having been powdered following a bath.

Stop 10. Paleosol along Falls Brook Road, Buckingham Township, Wayne County

Discussant: William Kochanov, Pennsylvania Geological Survey (Retired)

This stop is located approximately 0.35 miles west of SR 370 along Falls Brook Road (T611), Buckingham Township, Wayne County.

Coordinates: 41.931266, -75.298197 (Figure 10.1).

Buses will park along SR 370 to discharge attendees. We will then walk a brief distance to the stop.

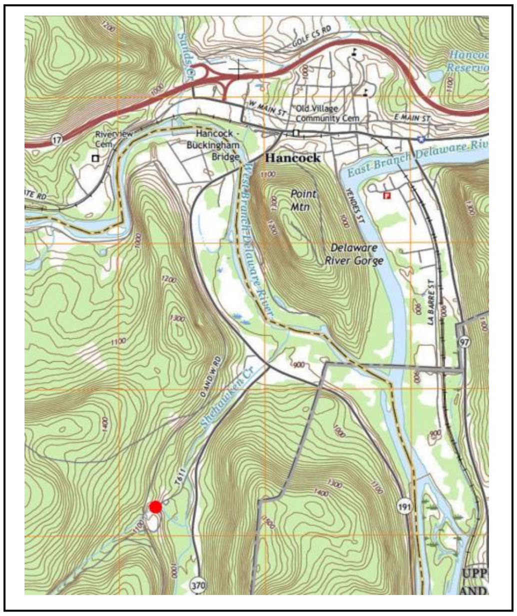


Figure 10.1. Location map. North is up.

Water level in the stream is typically low with the flow confined to a narrow channel. The terrain around the waterfall is likely to be wet and slippery. Caution is encouraged. Be sure of your footing before walking across or into the streambed. There is a path of sorts along the left side of the falls to view the jointed bedrock pavement above the falls. Use caution on navigating up the short but steep pathway.

Introduction

This stop represents the top of a fining-upward cycle and the onset of a new cycle. As examined yesterday at Stop 1, we envisioned the brownish-gray clays extending from the flanks of the river out onto the adjoining floodplain becoming the Catskill redbeds. We saw evidence for overbank deposits during high flow, starting with a poorly sorted medley of coarser-grained calcareous and non-calcareous pebbles and clasts (agglomerate) that graded upward into a distinctive wedge of sandstone that fanned out, draping sand over the floodplain, and finally, finer-grained sediments followed as the energy of the flood waters waned. Sedimentary structures such as mudcracks and burrows suggested wet and dry climatic conditions and root traces signaling the onset of soil development.

Stop 10 begins within the stream channel beneath the bridge. Traveling upsection, a well-defined, reddish-gray fine-grained, laminated sandstone grades into silty shales, becoming more argillaceous and more indistinctly bedded as one continues upstream. The continuum is capped by a more resistant silty mudstone, reddish gray at first, then changing color to greenish gray.

This paleosol cap marks the end of a fining-upward cycle. The new cycle begins with an erosive base and the deposition of a relatively thin bed of coarser lag sediments occurring at the base of the main channel sands. Calcareous clasts, nodules, and grains winnowed from pre-existing upland soils, river terraces, and weathered bedrock, are constantly contributed into fluvial drainages and become incorporated into the bedload of the stream and end up accumulating either as channel lag or as basal sediments of overbank deposits as observed at Stop 1. As Catskill sandstones, these calcareous components are oftentimes dissolved and can develop differential weathering patterns due to the presence of calcareous and noncalcareous layers (Figure 10.2).

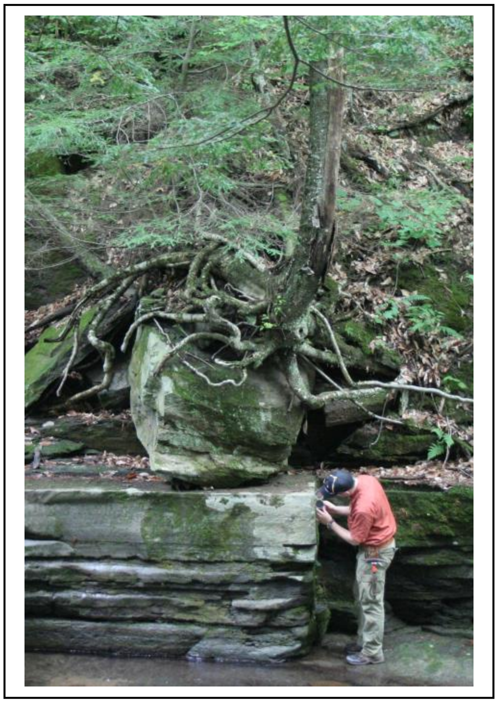


Figure 10.2. Calcareous zones are identified by recessed layers within the sandstones. They may be indicative of cyclic storm events where calcareous sediments are flushed into streams and in this instance, overrun the levees and drape across the floodplain.

At this stop, the calcareous lag grades upward into a series of stacked medium-sized beds of near horizontal, medium-grained, greenish-gray sandstone that separates along parting lineations spaced 5 to 10 cm apart. These sandstone beds can continue to fine upward into silty shales and claystone/shales but can also be interrupted by a renewed influx of relatively coarser mix of sand and intraformational calcareous clasts before returning to a fining-upward sandstone. This back and forth sedimentary cycle probably corresponded to seasonal flood and ebb sets within the drainage basin.

A closer look at the paleosol

The paleosol is benched from the erosive action of the stream and displays both A and B horizons. The stream-smoothed surface of the mudstone layer is a mosaic of polygonal outlines (desiccation cracks) ranging in size from 2 to 15 cm in diameter (Figure 10.3). The polygons continue as well-indurated columns extending down through the caprock for roughly 30 cm before grading into loose, angular to blocky, medium-grained (1-2 cm) peds (see Retallack, 1988, p. 12). The columns are calcareous in part probably due to the presence of calcareous cements and nodules(?). The crumbly base being less calcareous.

Note the rather sharp changing of color in the upper portions of the paleosol from reddish gray (B horizon) to greenish gray (A horizon), (Figure 10.4). This is reflective of a change from oxidizing (dry) to a more reducing (wet) environment. It is likely that the uppermost portions of the reddish-gray paleosol was feeling the effects of being water saturated. As the new fining upward cycle begins, there would be a corresponding influx of water and in turn, a higher water table thus providing the necessary reducing environment to initiate gleying – reducing iron and manganese minerals represented by the change in color.

Figure 10.3. Mudcracks. A. Yellow bar scale is 15 cm; B. Yellow bar scale is 5 cm. Note that there are smaller polygons within larger ones; C. Yellow bar scale is 15 cm. Mudcrack polygons translating into prismatic columns.

Figure 10.4. Paleosol showing a transition from reddish-gray to greenish-gray coloration. The greenish color marks a change from oxidizing (red, more dry) to reducing (greenish, more wet) environments.

A bit about the stream

The stream orientation is controlled by the regional joint patterns. Throughout much of Wayne and Susquehanna Counties, jointing is primarily twofold. There is a strong north-south component and a weaker east-west set. The e-w set is unique in that it can have a curvy trend (Figure 10.5). This can be attributed to a weaker imprinting of n-s stress compounded by the geometry and sedimentary structure of the sand bodies. This jointing pattern can also be observed beneath the bridge, or up top, just a bit upstream from the waterfall (Figure 10.5).

Figure 10.5. Curved east-west joints below waterfall (left), view east; streambed above waterfall, showing curved joint extending along length of stream (yellow arrow), with cross cutting north-south set (orange arrows), view north.

Stop 11. Catskill karst and colluvium

Discussant: William Kochanov, Pennsylvania Geological Survey (Retired)

Located approximately 245 m west of the intersection of SR 370 and Rose Hill Road, this stop includes the waterfall along an unnamed tributary to Shehawken Creek and outcrops to the north along the southeastern side of SR 370 in the woods.

Coordinates: 41.889497, -75.338502 (Figure 11.1).

The site skirts the southeast side of SR 370 just over the embankment into the woods. Mr. Reyes, the property owner, has kindly given us permission to use the road located behind his garage for access. Follow the trip leader to the stop. The terrain is uneven. Please watch your steps through the woods and along the cascading waterfall (particularly if there is water flowing). Some caution is suggested should one decide to travel on or alongside the highway (not advised). No littering.

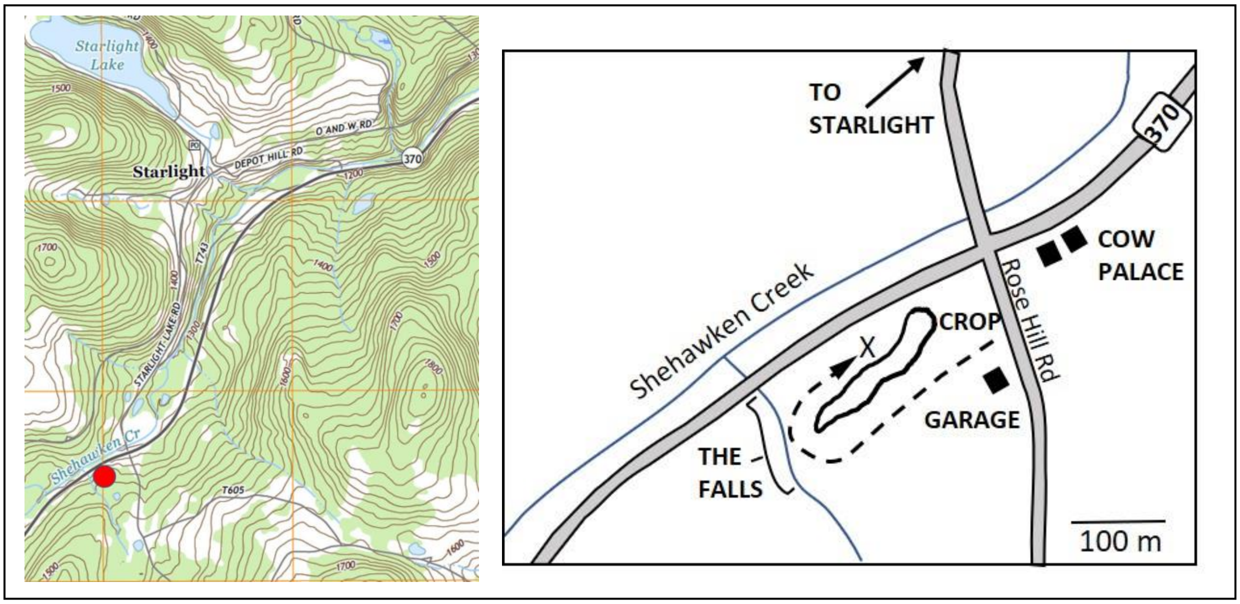


Figure 11.1. Location map. North is up.

Introduction

This stop brings together several basic concepts on the development of karst features within the Catskill Formation and how the dissolution process is just one step in the development of colluvium observed along many of the steep-sided hillsides in Wayne and Susquehanna Counties.

The story focuses on the calcareous lags and agglomerates occurring at the base of the sandstones mentioned previously during Day 1 (Stop 1) and Day 2 (Stops 1 and 3). They represent the erosional base of the fining upward cycle.

Being calcareous, they are more chemically active and responsive to the effects of naturally formed acids, primarily carbonic acid. They may also be affected by various types of lichens that seem to have a taste for calcareous strata (Figure 11.2). Over time, the acids slowly dissolve the calcite matrix and clasts creating small voids, recessed bedding, widened fractures, sculpted bedrock, and small caves (Figure 11.3a-c). Although the Catskill karst is somewhat similar to more traditional karst features observed in the limestone regions of the Ridge and Valley Province, it is limited in scale perhaps being more comparable to that observed in the western Pennsylvanian Vanport limestone where the calcareous beds are comparatively thin and are bounded in contact above and below by non-calcareous beds.

Figure 11.2. The “whitewash” lichen coating the surface of calcareous sandstones.

Figure 11.3. Catskill karstic features. A. widened joints and bedding partings, scale bar 1 m, station wo-20; B. small cave and pillars, scale bar 1 m, station sqme-9; C. recessed bedding, scale bar 1 m, station wlc-36 ; D. rock shelter, bar scale 2 m, station wh-18.

The voids created by the dissolution process undermine the overlying sandstone beds creating in some cases, rock shelters (Figure 11.3d). The weathered layers remove support for the overlying beds and causes them to separate along bedding and secondary parting lineations.

Catskill sandstone beds are bracketed laterally by a strong regional joint set; the dominant being north-south and a somewhat weaker, and sometimes curvy, east-west set. Once the voids have been developed, the overlying sandstones begin a cascading type of failure typically bounded by these joint sets. Aside from separating along parting lineations (Figure 11.4a), sections or blocks may fail en masse (Figure 11.4b). This process can occur repeatedly along the face of an outcrop (Figure 11.4c).

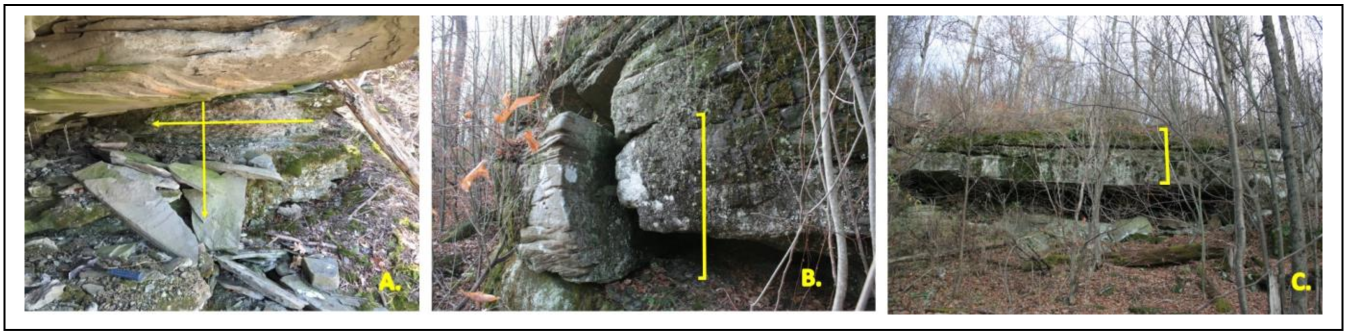


Figure 11.4. Breakdown. A. undercut direction (left arrow) then breakdown of laminated to thin- bedded sandstone, station ws-48; B. meter size block of bedded sandstone (bar scale) detached along joint, falling into bedding void, station wlc-44; C. approximately 14 m void beneath sandstone ledge, collapsed roof material in foreground, station wlc-42.

Coupled with the near vertical bedrock exposures and the adjoining steep slopes, large blocks may stack atop one another downslope creating secondary colluvial caves (Figure 11.5).

Figure 11.5. Stacked blocks of sandstone creating colluvial caves. Bar scales 2 m.

Live at the outcrop

At this stop, aside from the scenic waterfall, the sandstone outcrop is separated into large blocks, bounded by strongly defined joints and detached along bedding planes. The north end of the outcrop displays one of the recessed calcareous beds (Figure 11.6). Note the sculpted, smoothed surface and the overhanging ledge above. At this point in time, the stage is set. More recession is probably required along with some freeze-thaw action. Processes such as frost riving and congelifluction (Sevon and others, 1999) can also help separate outcrops along inherent fractures putting them in the position to move on down that rocky road.

Figure 11.6. Sandstone outcrop at Stop 10 showing calcareous bed partially removed by weathering. Note smoothed weathered surface and the overhanging ledge. Mr. Potter is approximately 1.8 m in height.

There are other oddities with bedrock movement that are a bit more difficult to model. For example, in Figure 11.7, note how the block at the base of the outcrop of sandstone has detached and moved relative to the outcrop. The end of the block in the foreground has pivoted to the right, note the triangular gap behind the block. It is as if the block was pried out. In Figure 11.7b, note how the central block has detached and separated from its roof. The block would have needed the void to develop first. It looks as if the rug was pulled out from beneath!

Figure 11.7. Oddities. A. A block of outcrop has detached and pivoted out (arrow). The block front – closest to the reader - has moved out approximately 0.5 m; B. It would appear that the basal block has moved to the left (arrow), creating a void, and undermining the block above.

Extra

One other karstic feature, not observed at this stop but worth mentioning, is the “anasazi” structures. The name taken from the cave like dwellings of the Anasazi of the American Southwest. The Catskill anasazi structure is similar in appearance but is a strictly small-scale feature (Figure 11.8). It is suggested that its formation is the result of dissolution on a granular scale. Many of the Catskill sandstones have fossil plant material occurring as lag deposits. The fossil plant material is often coalified and in some instances, the coaly material is replaced by pyrite. This replacement has been observed in core and on exposed sandstone surfaces (Figure 11.9). The reaction of pyrite with oxygen and water produces sulfuric acid much the same way oxidized pyritic material goes into forming acid mine drainage, a mining byproduct in some regions of Pennsylvania. Mobilized by groundwater and surficial waters flowing across the face of sandstones, the acidic water attacks the calcareous grains within the sandstone, creating a pitted surface and over time, sculpted vuggy openings.

Figure 11.8. Anasazi structures. Scale bar is 15 cm.

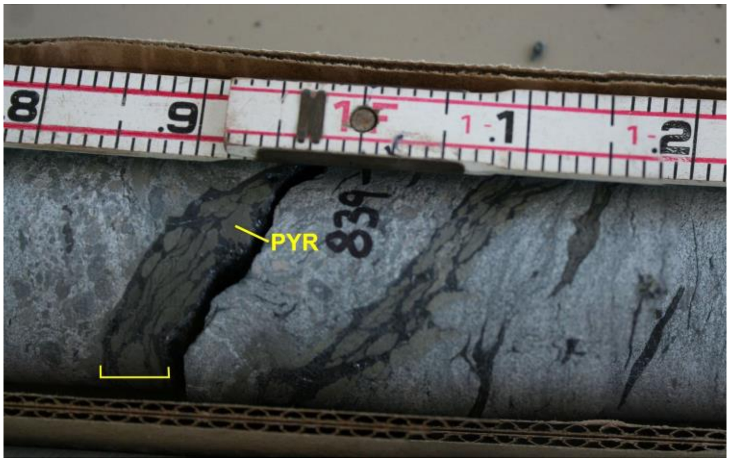


Figure 11.9. Section of core from the Clifford borehole, south knob of Elk Mountain, Susquehanna County showing coaly zones partially replaced by pyrite. Bar scale is 1 cm.

Stop 11A *(optional)*. The Starlight waterfall and landslide, Buckingham Township, Wayne County

Discussant: William Kochanov, Pennsylvania Geological Survey (Retired)

The waterfall is located approximately 0.5 miles north of SR 370 just west of the intersection of SR 4020 and the O&W rail trail. The landslide is located approximately 0.16 mile west of SR 370 along SR 4020, Buckingham Township, Wayne County (Figure 11A.1).

Coordinates: 41.903902, -75.330603 (falls) and 41.904406, -75.324924 (landslide).

Buses will park along the waterfall to discharge attendees. We will then walk a brief distance to the landslide.

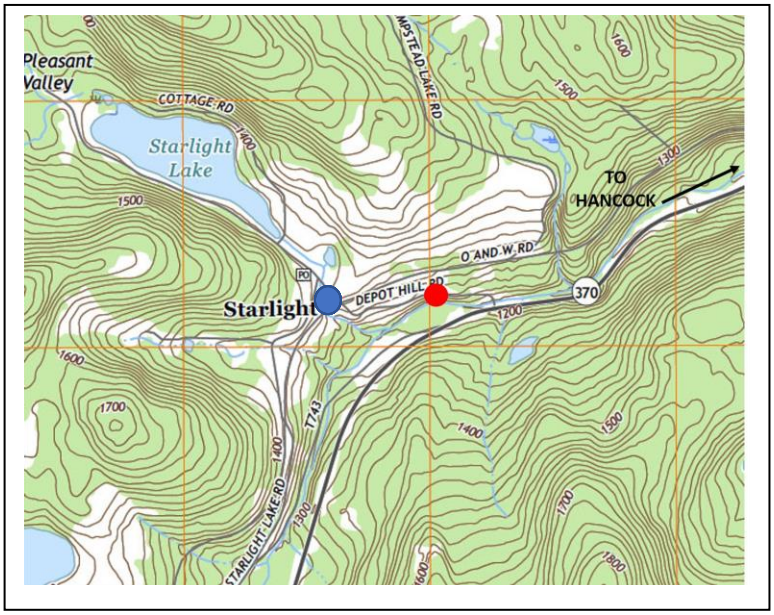


Figure 11A.1. Location map. North is up. Waterfall is blue dot. Landslide is red dot.

For safety reasons, the property owner does not want individuals clambering down the hill to get a close up view of the waterfall. We will have to be content with the view from up top. As geologists, we should all want to view the landslide, it is worth the walk. As always, caution is encouraged. One can stand just about on the rim of the slide to enjoy the view without falling down the steep, and I mean steep, hill. Don't take chances.

The waterfall

The "Starlight" waterfall, like so many waterfalls in Wayne County, has developed from a combination of factors: steep slopes, a sandstone base, shaly or calcareous bedding partings, differential weathering, water, and time. The key to the drainage along the steep hillsides is the regional jointing pattern (see Stop 9). Sandstones, being more brittle, have better established jointing and it would seem likely to provide the essential conduits for groundwater flow (Figure 11A.2). Over time the action of physical and chemical weathering of bedrock can further enhance flow along these bedding fractures as well as bedding partings.

Figure 11A.2. Groundwater discharging from open fractures in a Catskill sandstone. Photo from Kochanov station ff-54, Franklin Forks 7.5-minute quadrangle, Susquehanna County.

As we have observed at other stops, there are calcareous grains and beds within the Catskill that are subject to dissolution (e.g., Stops 1, 9, and 10) and over time create voids and lead to breakdown of overlying strata. At this Stop one can see the areas of breakdown initiated by the weathering of the calcareous components (Figure 11A.3) creating the benched appearance and the cascading effect.

Figure 11A.3. The “Starlight” waterfall showing its steps and aesthetics.

The landslide

The steep-sided hillsides abutting the stream drainages are typically lined with glacial outwash throughout Wayne County (Figure 11A.4). The steep-sided and narrow valleys are periodically flooded creating unstable conditions for the valley walls and subsequently, roadways that follow the valley bottoms. During these flood events, stream flow rises and the characteristic turbulent flow erodes the base of the unconsolidated glacial and alluvial sediments lining the valley sidewalls. This undercutting at the toe of the slope removes support for sediments and vegetation higher up along the embankments. This Stop is a nice example of the end result of this erosional process (Figure 11A.5).

Figure 11A.4. Glacial outwash along Faulkner Brook, a steep-sided stream valley in the Hancock 7.5-minute quadrangle.

Figure 11A.5. View from above and alongside of slide area at Stop 10A. Note cobbles and pebbles in glacial outwash along slope and below root mass.

Stop 12 . The Missing Catskill, Elk Mountain, Susquehanna County

Discussant: William Kochanov, Pennsylvania Geological Survey (Retired)

This stop is located approximately 5.5 miles west of Herrick Center on SR 374.

Coordinates: 41.723405, -75.553427 (lodge), 41.715385, -75.560576 (Elk Mountain, north knob) (Figure 12.1).

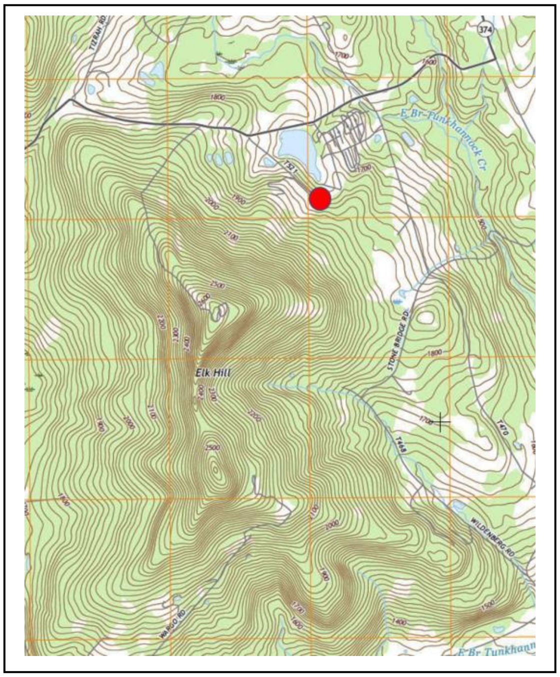


Figure 12.1. Location map. North is up.

Due to logistical issues, i.e., the road to the top is not navigable by bus and the alternative, take attendees to the summit by ski lift would have taken too long (~2-3 hours round trip). As it is, we will gaze upon Elk Mountain from the ski lodge veranda and arm wave from there.

Introduction

> “On a bright November day the five lakes in the immediate vicinity glistened in the sunlight; though they were not then "gems set in emerald wreaths," for the hills were brown and the forests faded to somberness. Yet, the scene was full of grandeur, impressing one principally with its vastness. "The sea! the sea!" was the idea presented by the view along the wide horizon, for the hills were as billows on billows; white sails were imaged in painted houses far away, and, in some places these crested the hills as foam crests the ocean.”

Such were the poetic impressions of Emily Blackman (1878, p. 383) peering out from atop Elk Mountain’s north knob. Elk Mountain actually has two peaks; the main summit of North Knob at 2,693 feet (821 m), and the lower summit known as South Knob at 2,602 feet (793 m). Its cousins, 8-9 mi (12 - 14 km) to the northeast, Mt. Ararat (2634 feet/803 m) and Sugarloaf Mountain (2529 feet/771 m) make up anomalous high points on a rather uniform plateau (Figure 12.2).

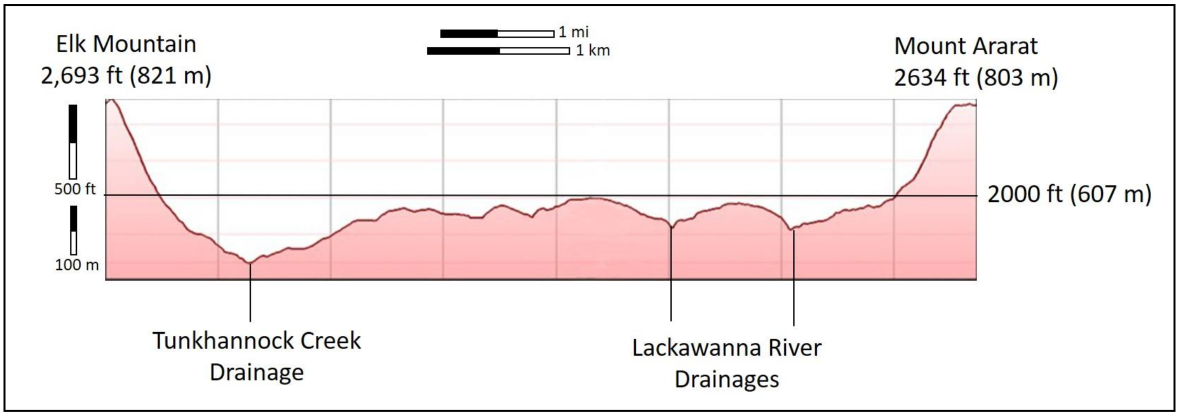


Figure 12.2. Cross sectional profile of the land surface from Elk Mountain to Mount Ararat. Note the middle plateau. Image captured from Google Earth Pro's elevation profile function and modified with Adobe Photoshop and MS Powerpoint.

Up to now, we have been examining the Catskill Formation from the local base level hanging in the general range of 1640 feet (500 m) to 1970 feet (600 m) above msl. This is fairly evident if we were to be looking from the crest of the north knob (Figure 12.3) across the broad plateau profile shown in Figure 12.2. Based on the relatively low bedding dips (<5 degrees), there is not much variation in stratigraphic range from one county to the next.

Figure 12.3. View from the north knob of Elk Mountain looking east. View of Elk Mountain looking west.

Elk Mountain and Mount Ararat

Kochanov also visited the north knob of Elk Mountain, in 2001, expecting to find sandstone holding up the mountain. He did find sandstone, but it turned out to be reddish gray. It was a series of thin- to medium-bedded sandstones serving as the base for a series of stacked fining-upward sequences (Figure 12.4). He recorded the data, interpreting the exposure as part of the Catskill Formation; this basically is in agreement with the present state geologic map (Berg and others, 1980; Miles and Whitfield, 2001).

Figure 12.4. Fining-upward sequences atop the north knob of Elk Mountain. View is west.

Approximately 8 miles to the northeast is Mount Ararat. Willard (1939) produced a generalized geologic map of northeastern Pennsylvania (1939, insert map Figure 72) using much of I.C. White's stratigraphic nomenclature. One point of interest is that Willard mapped the Pocono Formation at the summit of Mount Ararat in contact with the Catskill Formation. This in turn has been brought forward on successive state geologic maps down to the present.

Kochanov and Victoria Neboga (PAGS) examined this marvel in 2016 and sure enough, capping the summit of Ararat Mountain was a medium-bedded, light gray, coarse to very coarse sandstone and small pebble conglomerate (Figure 12.5). In character, it tends to be more closely aligned with lithologies common to the Lower Mississippian Pocono Formation. The coarseness and conglomeratic character of the rocks differentiated them from the typically fine-to medium-grained sandstone of the Catskill. Additionally, patches of broken up Catskill redbeds along the roadway and redbeds outcropping in a nearby shale pit (Kochanov stations WO-29 and 30) were observed approximately 10-15 meters below the Pocono sandstone outcrops.

Elk and Ararat represent the highest elevations in Susquehanna and Wayne Counties. Both provide evidence of Catskill lithologies (redbeds), with the Mount Ararat site adding some evidence of an unconformable contact between the Catskill and Pocono Formations.

Figure 12.5. Outcrop of Pocono Formation sandstone (left); closeup (right), arrow pointing to larger white quartz pebble.

Bedrock mapping projects associated with the 2015-2017 PAGS/USGS Statemap programs included the drilling of two cored boreholes, one in Wayne County (WAY127-0426) on State Game Lands 70, and the second in Susquehanna County (SUS115-0466) atop the south knob of Elk Mountain. Drilling was to assist in regional correlations, to ascertain if the Catskill could be differentiated into mappable members, and to obtain a reliable thickness for the Catskill. The Marine Lock Haven Formation was set as the target horizon.

The borehole on the south knob of Elk Mountain encountered redbeds at the onset, comparable to those noted on the north knob. Indeed, fifty percent of the top 500 feet of drilling was redbed lithologies (Figure 12.6). This provided some credibility to the Catskill interpretation. There were thoughts that much of Elk Mountain may have been part of the transitional Mississippian/Devonian Spechty Kopf Formation. More on that later.

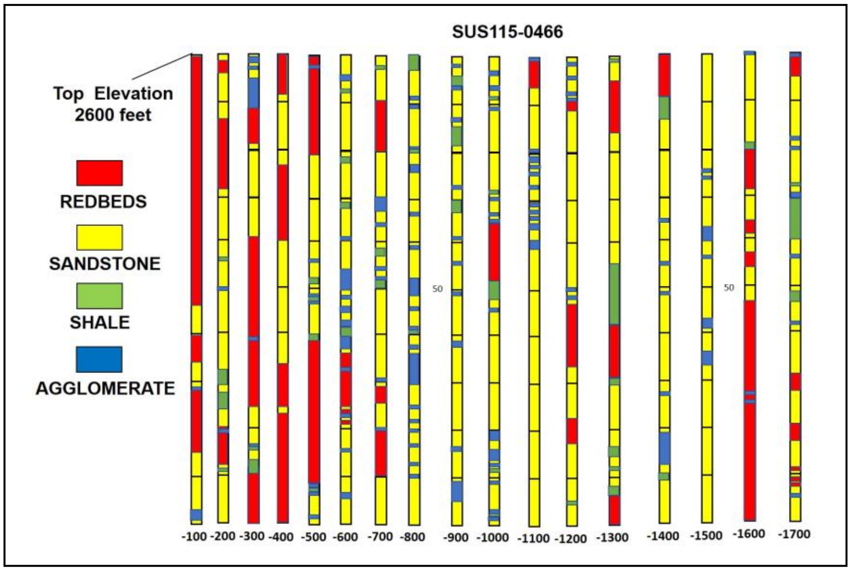


Figure 12.6. Graphic showing lithologies logged in the Elk Mountain borehole. Depths shown across the bottom. Note the high percentage of redbeds in the top 500 feet.

The elevated percentage of redbeds in the top 500 feet is noteworthy for it represents the missing Catskill over much of Susquehanna and Wayne Counties. It is a fact that many of the rock exposures across the “broad plateau” are either sandstone or sandstone colluvium. Where are the redbeds? One answer is that being composed of finer-grained sediments they tend to be more easily erodible. Braun (2004) cites evidence for four different glacial advances across the Tunkhannock - Great Bend area. So, it follows that glaciation, and associated periglacial and post-glacial weathering and erosion, probably removed most of the redbeds between Elk and Ararat high points leaving behind the more prominent (and more resistant to weathering) sandstone.

A bit about the Spechty Kopf

The extra footage of stratigraphic section that Elk and Ararat provide above the regionally established base level suggested by Figure 12.2, tossed possibilities into the minds of the mappers that it may represent rocks above the Catskill.

The state geological map and bedrock mapping by Kochanov (1997, 2000) shows the Mississippian Spechty Kopf Formation, along with the Mauch Chunk Formation, not extending northward much past Archbald in Lackawanna County. Aside from rare hilltop exposures, such as the occurrence atop Mount Ararat, the Pocono also does not continue northward along those lines. This suggests that regional unconformities may have extended over portions of Lackawanna, Wayne, and Susquehanna Counties or that those Mississippian units were just never deposited this far north.

Unconformities at this stratigraphic interval have been identified in the western part of the anthracite field, Trexler and others (1961). They determined that the upper part of the Catskill is unconformably overlain by the Pocono. Additionally, they also concluded that an unconformity also separates the Spechty Kopf from the Pocono in the type area and throughout the western part of the anthracite region.

Perhaps it was time to check on the type section of the Spechty Kopf just to be sure. Following the thread of the Spechty Kopf back to its roots, Trexler and others (1962) stated that the “exposures of the Spechty Kopf member are poor and the authors have not able to find a complete or nearly complete section” (p.C37). Be as it may, they characterize the upper Spechty Kopf as consisting of, “almost equal amounts of the gray and olive-gray sandstone and fine conglomerate, and red beds” (p. C37). There is not much guidance as to what “red beds” implies. As far as the lower section goes, “it consists chiefly of gray and gray-green sandstone, shale, and fine to coarse quartz-pebble conglomerate with a few intercalated thin red beds… (the lower contact is) gradational and is placed arbitrarily at the horizon where gray- and olive-hued beds characteristic of the Spechty Kopf predominate over red beds characteristic of the main body of the Catskill” (p. C37).

As we have seen from yesterday and today, red beds seem to define the Catskill, at least in a lithologic perspective. Perhaps Arndt and others (1962, p. 36) found the words that may as well speak for the Catskill in Wayne and Susquehanna Counties, “The sedimentary features of the Catskill in the western part of the anthracite region are not plentiful or diagnostic enough everywhere to indicate clearly the environment conditions under which the rocks were deposited therefore it is not practical to attempt subdivisions of the Catskill strictly on the basis of marine or terrestrial rocks.”

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Preconference Field Trip: Haystack Rapids, Loyalsock Creek – October 3, 2019

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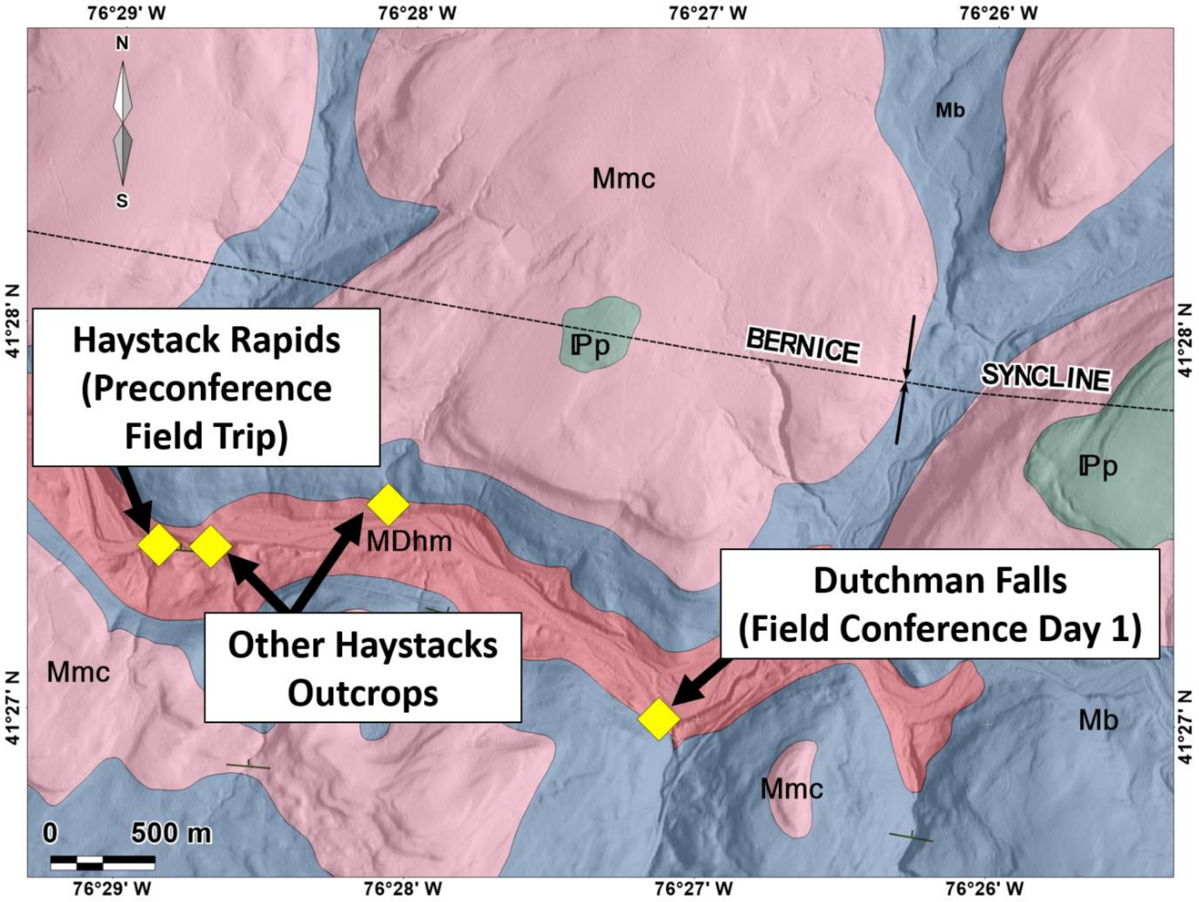

***Figure 1**: Portion of geologic map of the Laporte 7.5' quadrangle showing location of the Haystack Rapids location (preconference field trip) and the Haystacks outcrop at Dutchman Falls (Field Conference Day 1)*

Location: Lat 41.457186 N, Long -76.481012: Haystack Rapids, Loyalsock Creek

Key Points:

1) Type section/area for the Haystacks interval.
2) Discontinuous regional marker "horizon" of orthoquartzite/silica-cemented sandstone, approximately 1.5 m thick
3) Upper Huntley Mountain Formation (Devonian – Mississippian).
4) Distinctive lithology, massive, and resistant to erosion.
5) Represents a silcrete formed from groundwater processes.

Introduction

This hike is an opportunity to view and discuss the enigmatic “Haystacks” interval at Haystack Rapids along Loyalsock Creek. The hike will take us through fluvial channel-bar facies of the Burgoon Sandstone and the Huntley Mountain Formation. Much of the hike is along the eastern end of the Loyalsock Trail, which partially follows an old railroad grade. The Haystacks is an orthoquartzite/silica-cemented sandstone that is massive and highly resistant to weathering and erosion. As a result of its indurated nature, the flow of Loyalsock Creek has rounded these blocks of orthoquartzite/silica-cemented sandstone into shapes resembling haystacks. The distinctive appearance of the Haystacks relative to the bounding stratigraphic units suggests that it could be useful as a correlative horizon within the Devonian – Mississippian fluvial succession. We will be visiting another outcrop of the Haystacks interval at Dutchman Falls on Day 1 of the Field Conference.

Geologic Setting

Haystack Rapids is located on the south limb of the Bernice syncline and stratigraphically within the upper part of the Huntley Mountain Formation (Devonian – Mississippian) (Fig. 1). The strata in this area dip to the north-northeast 3˚ to 8˚. The Huntley Mountain Formation overlies the Catskill Formation and was deposited in low to moderate-sinuosity rivers that flowed west. The Huntley Mountain Formation is primarily a sandstone-dominated unit, interbedded with zones of red to green shale and siltstone. The finer-grained intervals don’t preserve well in outcrop but are observed in core and well logs, ranging from 6 to 9 m thick. Along the hike to the Haystack Rapids, there is outcrop along the railroad grade that documents the gradational nature from the upper Huntley Mountain Formation into the overlying Burgoon Sandstone. The Huntley Mountain Formation is characterized by distinctive cross bedding that gives the gray-green sandstone a slabby appearance. The slabby sandstone beds are 2 to 5 cm thick and very fine to fine-grained. The overlying Burgoon Formation is more of a buff color and overall medium to coarse-grained with conglomeratic zones containing clasts 5 mm to 1 cm. Crossbed sets range from 10 to 50 cm thick and are thicker bedded than the thinner, slabby character of the Huntley Mountain Formation.

Haystack Rapids

The westerly flowing Loyalsock Creek forms Haystack Rapids amongst the mounds of highly resistant, orthoquartzite/silica-cemented sandstone (Fig. 2). These mounds extend across the creek to the north bank and can be traced approximately 75 m along its length. Depending on the water level, the Haystack mounds are 3 m to 15 m in diameter and are up to 1 m above the water line (Fig. 3). Where the base and

Figure 2: *View of the Haystacks looking upstream, to the east.*

top of the Haystacks are visible in outcrop along the south bank, the thickness of the interval is 1.5 m (Fig. 4). Other outcrops of the Haystacks can be intermittently traced upstream, approximately 200 m (Fig. 5)

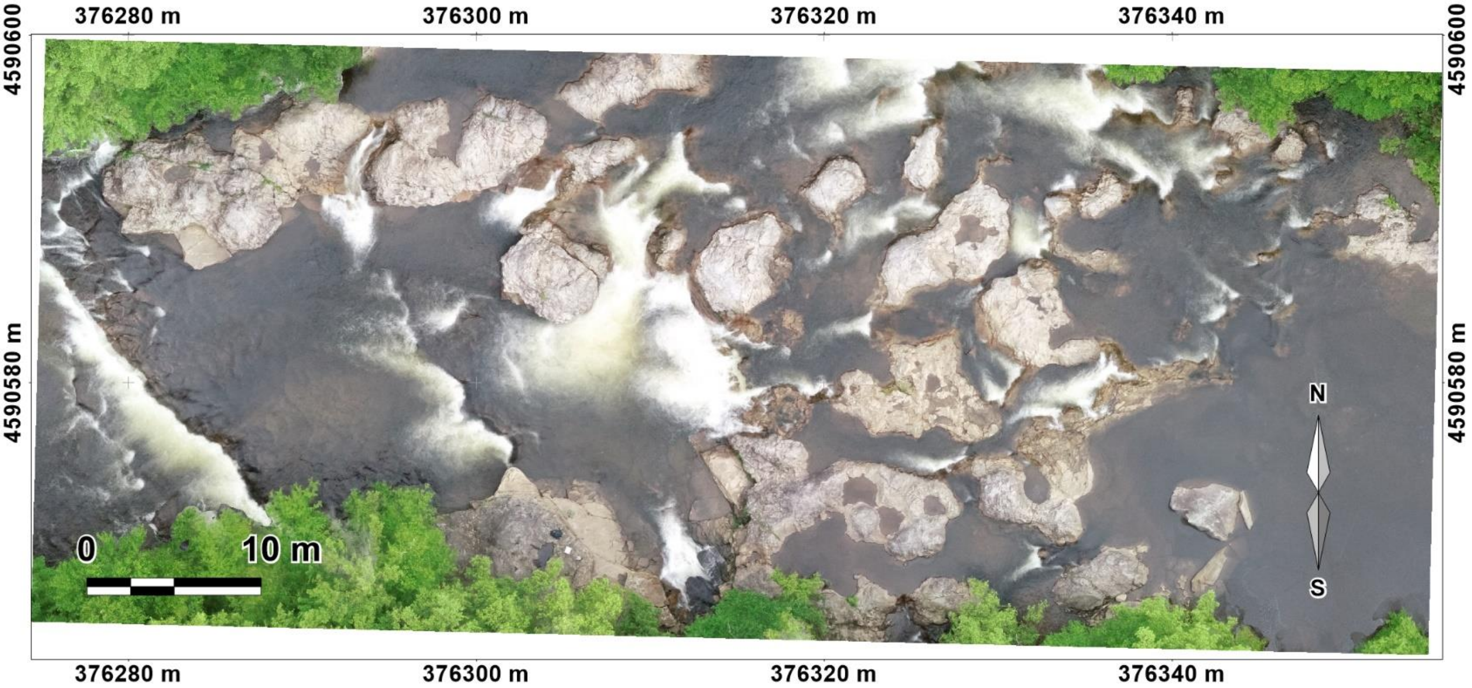

Figure 3: *Aerial view of Haystack rapids, showing the individual mounds of orthoquartzite.*

Figure 4: *Outcrop of the Haystacks on the south bank of Loyalsock Creek. The arrow marks the base of the Haystacks. White lines define the foresets of the underlying crossbedded sandstone. The Haystacks lack the crossbedding that is common in the Huntley Mountain Formation.*

Figure 5: *The Haystacks interval exposed on the north bank of Loyalsock Creek, approximately 200 m north of Haystack Rapids. Red line denotes the undulating upper surface of the Haystacks.*

Petrology

The petrographic characteristics of the Haystacks were documented in earlier studies (Gillmeister and Springer, 1993; Hill, 2007; Hill, 2008; Hill and Jimenez, 2010). The distinctive appearance of the Haystacks relative to the Huntley Mountain Formation not only applies to outcrop, but also at the microscopic scale. The Huntley Mountain Formation has higher concentrations of clay minerals, muscovite, and polycrystalline quartz with grains showing slightly more angularity. The Haystacks are much cleaner, compositionally, and dominated by monocrystalline quartz with microcrystalline quartz cement.

Silcretes

The literature describing silica-cemented sandstones within fluvial successions considers such intervals a result of silcrete formation (Nash et al., 1998; Shaw and Nash, 1998; Ullyott et al., 1998; Ullyott and Nash, 2006; Nash and Ullyott, 2007; Ullyott and Nash, 2016). Silcretes, as originally defined, refers to gravel and/or sand, in which silica replaces and/or accumulates to form an indurated mass (Ullyott and Nash, 2006; Nash and Ullyott, 2007). Furthermore, they are considered a result of near-surface processes and can be attributed to both pedogenic and nonpedogenic origins (Ullyott et al., 1998; Ullyott and Nash, 2016). The types of nonpedogenic silcretes include groundwater and drainage-line varieties (Ullyott et al., 1998; Ullyott and Nash, 2016). They form below the land surface and are related to the water table and/or groundwater flow. In settings where these silcretes are documented their geomorphological position is within or along the margins of the channel system.

The Haystacks are similar to silcretes interpreted as capping braided channel systems within the Cretaceous Cedar Mountain Formation near Green River, Utah (Fig 6). These silcretes have a varnished appearance and still preserve cross bedding (Fig.7), as opposed to the more massive Haystacks. The silica cementing the sandstone of the Cedar Mountain Formation is chalcedony compared to the microcrystalline quartz observed in the Haystacks (Fig. 8). These Cretaceous silcretes are laterally discontinuous and have been observed capping channel belts at various stratigraphic levels. The variability in the occurrence of the silcretes could be a model for the distribution of the Haystacks, suggesting that the Haystacks are not a single, stratigraphic horizon but likely a zone or zones of silcrete formation

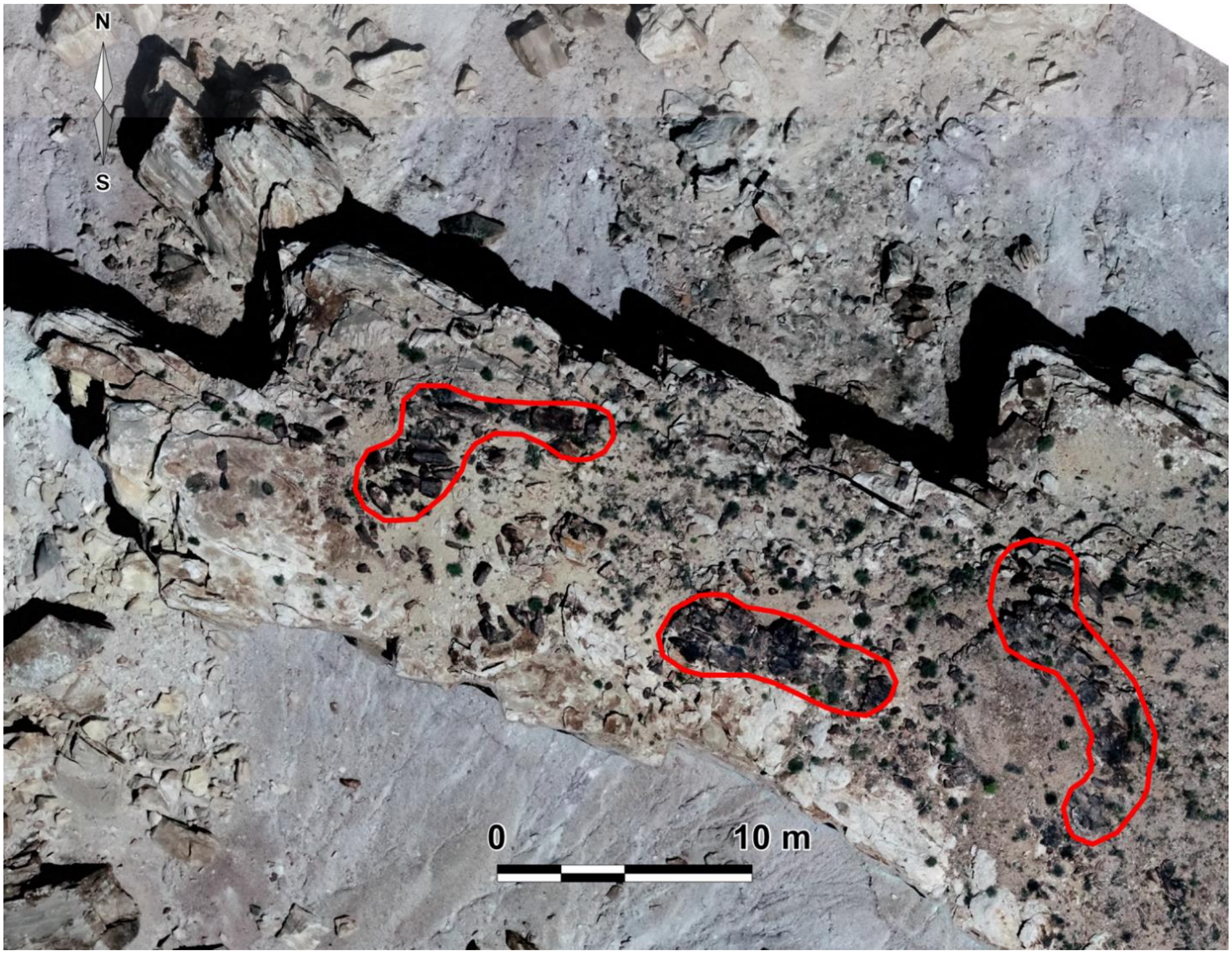

Figure 6: *UAV image of a Cretaceous braided channel belt within the Cedar Mountain Formation in Utah. The darker patches, outlined in red, are silcretes that form a discontinuous cap.*

Figure 7: *Photograph of a silcrete, capping the top of a channel belt in the Cedar Mountain Formation. Base of the silcrete is marked by the red line.*

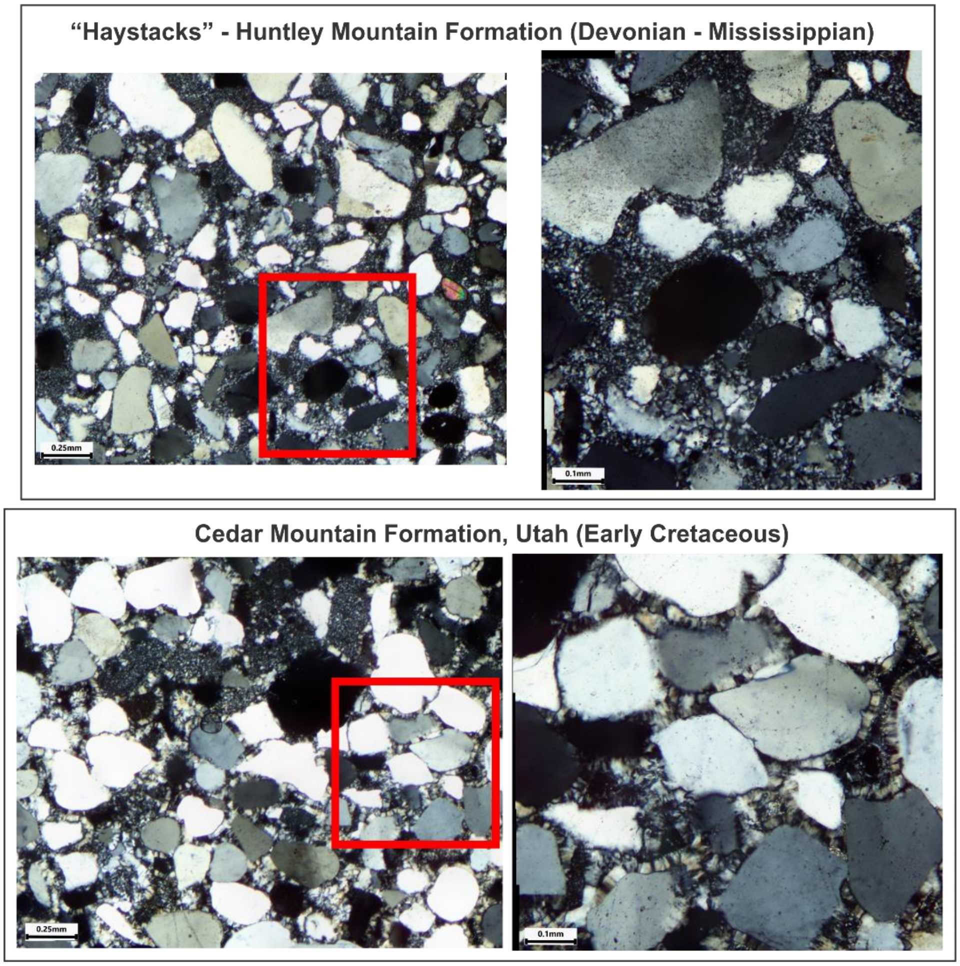

Figure 8: *Photomicrograph comparison of the Haystacks with silcrete from the Cedar Mountain Formation in southern Utah.*

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Supplemental Sites

Site 1. Catskill sandstones, State Game Lands 159.

Visitors must follow all Game Commission regulations. During hunting season Sunday access ONLY. In addition groups of more than 10 must apply for a Special Use Permit. It takes a while for the Game Commission to review permits so apply early!

https://www.pgc.pa.gov/HuntTrap/StateGameLands/Pages/SpecialRequestsonGameLands.aspx

Figure 1. Location map for supplemental Site 1, 1a, 2a, and 3a.

At **41.759650, -75.283950** bear right onto Fork Mountain Road, head towards Upper Woods Pond. Park at **41.762765, -75.281683** just before the gate. If gate is open, it's probably hunting season, October through December. Usually it is locked. Follow the gated road for about 15-20 minutes, there will be a cleared area on the right that is used for parking (**41.768974, -75.275328**). Continue for about ~250 feet past the clearing. At approximately **41.769704, -75.274298** just before the road kinks a bit to the right, enter the woods on the left and walk for about 750-800 feet. Initially the footing may be a bit wet to rocky the first 100 feet or so, you'll see. Aim for dryer ground to the right as you bear due west. You should start seeing outcrop on the right as you are walking. Follow the outcrop, it will eventually curve northward. Essentially you are there at **41.770696, -75.276735** (Figure 1). There will be a nice "platform" to walk alongside the outcrop northwards.

What you will see

Sandstone (Figure 2), medium gray to medium olive gray although weathered colors can impart some olive and reddish orange; medium to very coarse grained, calcareous in part; bedding is near horizontal to shallow trough cross bedded, crossbeds angle to 10 degrees, beds range 2-3 feet thick; thinly laminated; minor calcareous agglomeratic (intraformational conglomerate) beds 0.5 to 2 feet thick separating sandstone beds; bedding dip direction 2 degrees, N80W; joint 1 N16E, 90 degrees; joint 2, N85W, 90 degrees.

Figure 2. Stacked medium beds of near horizontal planar and planar cross stratified character (left); massive breakdown along joint and bedding planes initiated by weathering of calcareous beds (right). Scale (bar and individual) is 6 feet.

The primary items are the stacked beds of near horizontal and low angle trough cross bedded sandstone, voids as one walks the crop, as well as the commonly occurring sections where breakdown has occurred (same story as told at Stop 10, Day 2). Shifting distributary channels could account for the offset stacked trough cross bedded sandstones.

There are other outcrops in the woods if one wishes to journey further.

1a. 41.776666, -75.270206 nice sandstone section ~40 foot in height (Figure 3) displaying much the same as Site 1 but larger in scope.

2a. 41.776510, -75.270620 part of the same outcrop sequence, just a bit south and east of 1a; close up of anastasi structures (Figure 4).

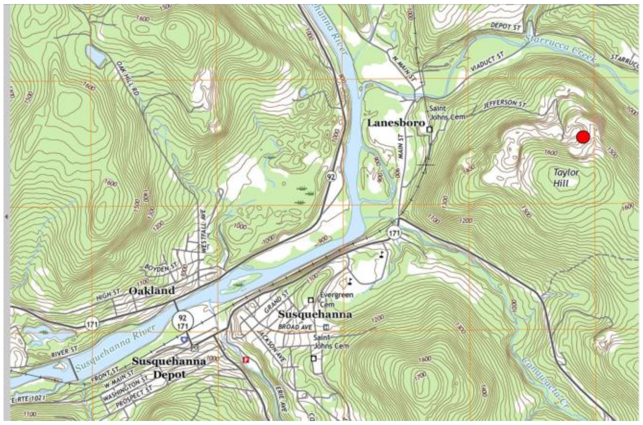
3a. 41.778140, -75.280030 the ship rock (Figure 5) station WLC-39. A seemingly detached outcrop of sandstone beds.

Figure 3. Additional stop 1a. Outcrop (left); slump? structure between sandstone beds (right).

Figure 4. Additional stop 2a. Outcrop (left); Satellite outcrop (left) of 1a, showing anasazi structures (right).

Figure 5. Additional stop 3a. “Ship Rock”, a large island of Catskill sandstone.

Site 2. Smoky quartz crystals and fluid inclusions at the Lanesboro Quarry.



Intersection Main St. with Jefferson Street, 0.92 miles on Jefferson to office **41.962076, -75.572095;** continue to east quarry **41.959965, -75.567636.**

Figure 6. Location map for the Lanesboro quarry.

What to see

Large inactive quarry showing several benches of fining upward cycles (Figure 7). Quarry noted for calcite and quartz filled N-S fractures. Western highwall covered with opaque gray and clear smoky quartz crystals (Figures 8).

Figure 7. View of Lanesboro quarry showing expanse of redbed sequences.

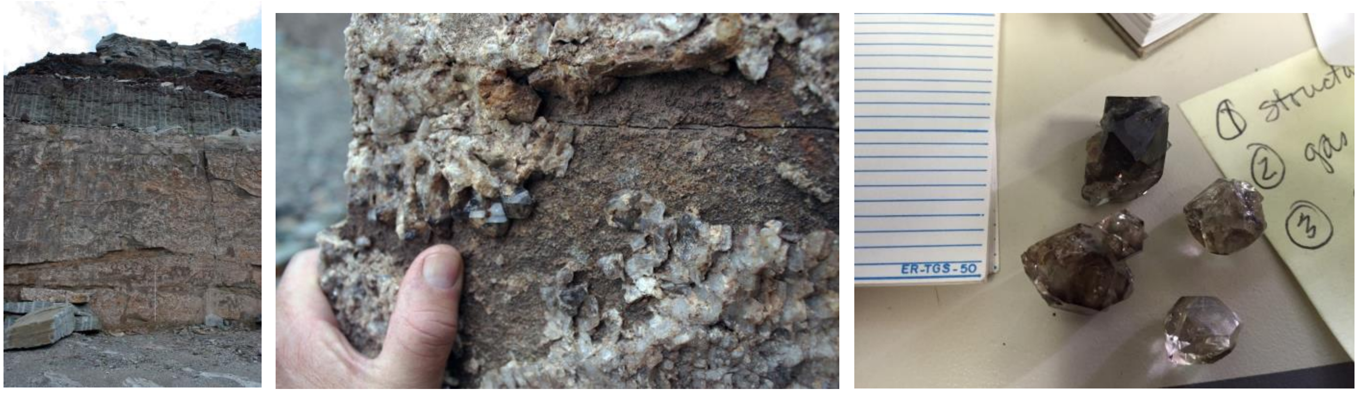
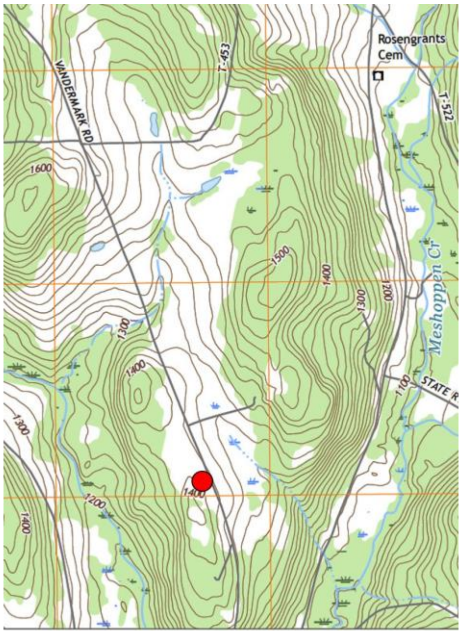


Figure 8. Highwall of the Lanesboro quarry covered with patches of quartz crystals (left), scale at base 6 feet; close up of smoky quartz crystals on N-S joint face (middle); crystals (right).

Site 3. Fish Burrows.



41.754850, -75.857510 Vandermark Road; 0.6 mi N of intersection with SR 2024 (Figure 9). Owner is first house north on left, Vandermark Road.

Figure 9. Location of the "fish" burrow quarry

What to see

Relatively small roadside flagstone quarry (Figure 10) with very nice fossil fish? burrows (Figure 11). Some discussion as to whether the round features are faunal or floral in origin. They seem to be a bit too clean in outline for a burrower, considering their size and considering the physical shape of Devonian fish. The "hairy roots appear to be associated with the round structures.

The mine is currently active (as of summer 2019) and the status of the fossil layer is not good, i.e., it was covered by work up above the road level quarry. However, this does bring up the possibility of uncovering more structures in the future, making it worthwhile to visit periodically.

Figure 10. The "fish burrow" quarry.

Figure 11. Fossil fish burrows (left); burrows and "hairy fossil roots (right).

Site 4. Rock Ridge Stone.

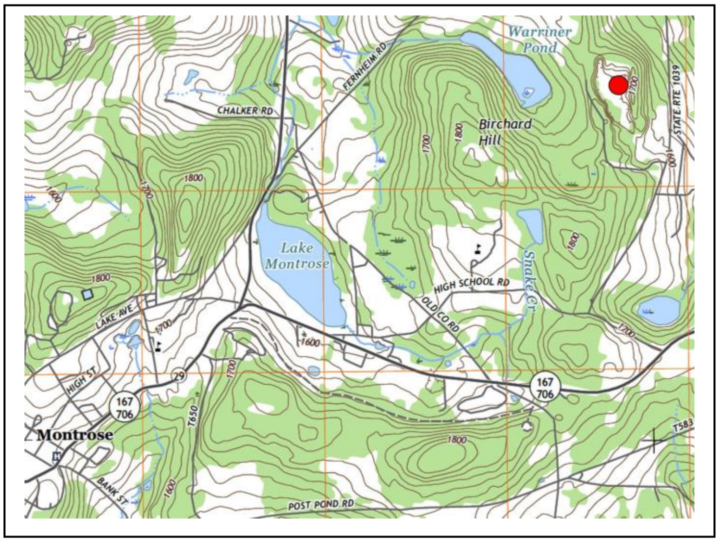


Figure 12. Location map for the Rock Ridge Stone quarry.

41.850280, -75.835530 intersection SR 706 and SR1039 (Hospital Road)

OFFICE: 41.848008, -75.832644; get permission from office.

What to see

The sandstone beds at northeastern highwall display curved joints possibly controlled by the primary geometry of the sand body. Some interesting deformation of sandwiched shale interbeds. Fining upward cycles. Also a unique method of sealing flagstone, something to do with flames?

Figure 13. Eastern highwall showing “curvy” joints.

Figure 14. Eastern highwall showing basal erosive calcareous agglomeratic bed.

Site 5. Ararat.

Road entry along SR 670 at **41.786064, -75.445028;**

Gated road to county 911 communication tower **41.785798, -75.459108.**

Follow crest of ridge north. Catskill shale pit **41.788762, -75.457861;**

Redbeds on left side of road ground level **41.789830, -75.457560;**

Pocono? sandstone road level **41.790470, -75.456920;**

Pocono sandstone **41.791437, -75.456331;**

Pocono sandstone **41.792853, -75.454950. Figure 20.**

What to see

Mapped as Pocono by White (1881), the outcrop lies atop nearby redbeds. A bit of a hike taking the county 911 tower roadway. It is gated but worth checking to see if it is open.

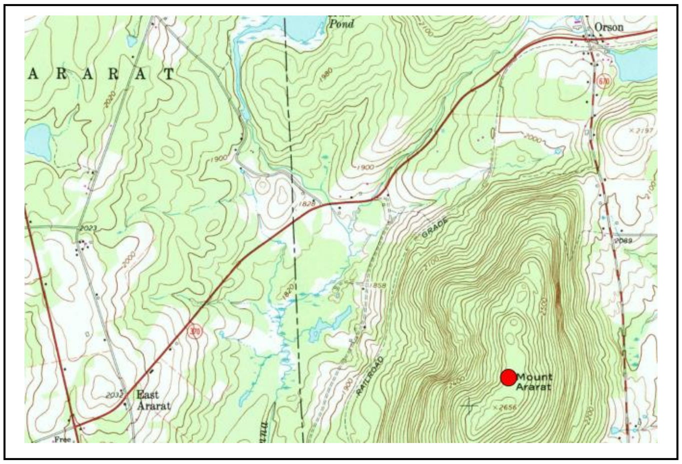


Figure 20. Location map for Mount Ararat.

Photos, see Stop 11.

Site 6. Karst in Catskill. 41.844022, -75.356039 along Woods Road. Figure 21.

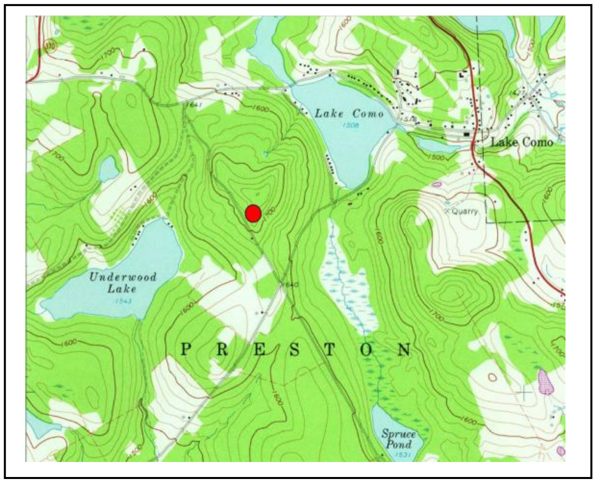


Figure 21. Location map for outcrop showing karstic features in Catskill sandstone.

What to see

A 100-meter outcrop angling through a patch of roadside woods. The outcrop displays weathered interbedded calcareous agglomeratic sandstone and non-calcareous sandstone resulting in a karstic appearance. A small cave is at the south end of the outcrop near the road.

Figure 22. Outcrop showing recessed weathering of calcareous agglomeratic sandstone beds.

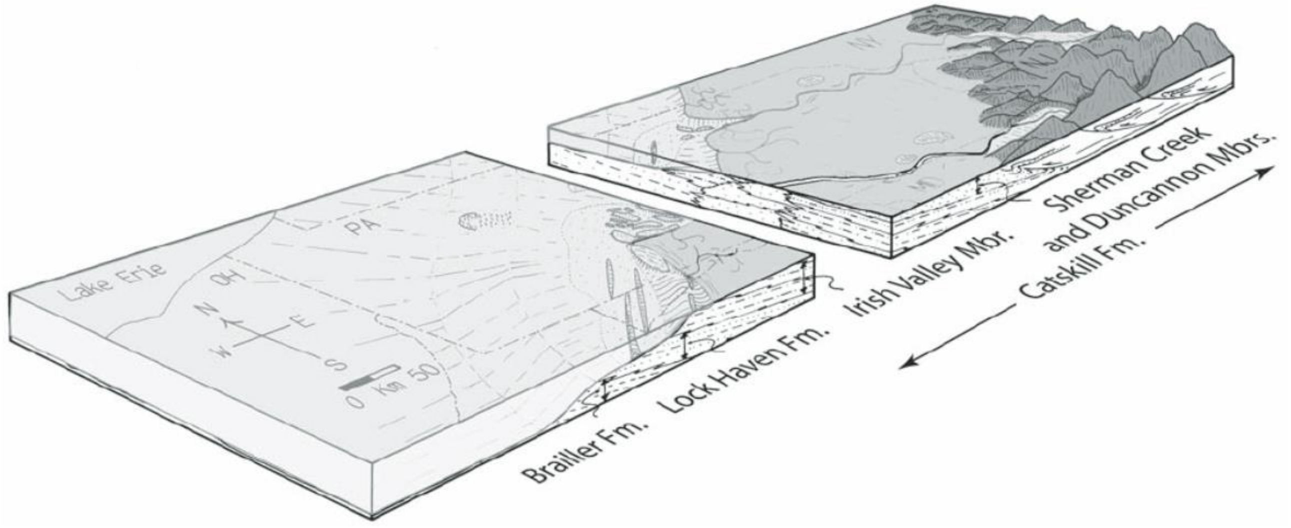
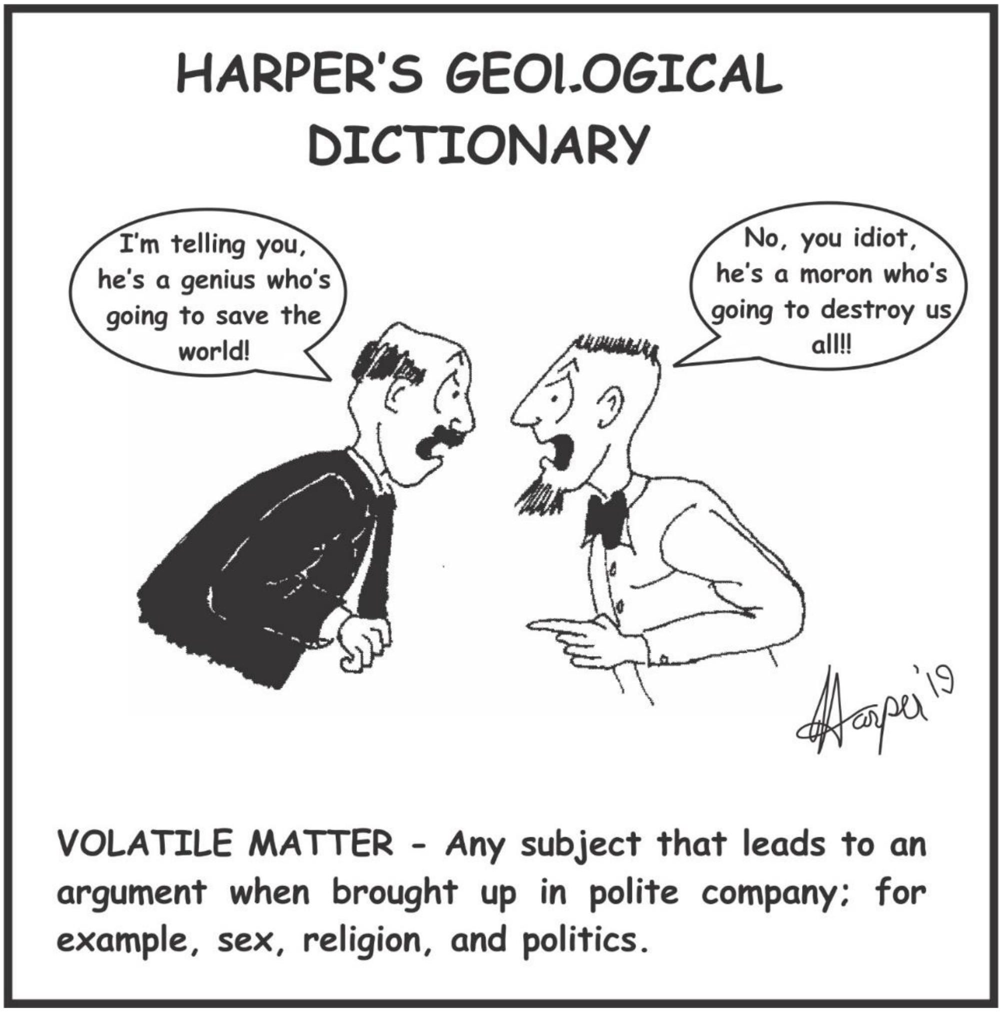


Figure 1. Block diagram of depositional systems of the Catskill Delta Complex during the Late Devonian in Pennsylvania. Reprinted from Cressler et al. (2010a).



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"for every 3 geologists, there are 5 opinions."

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