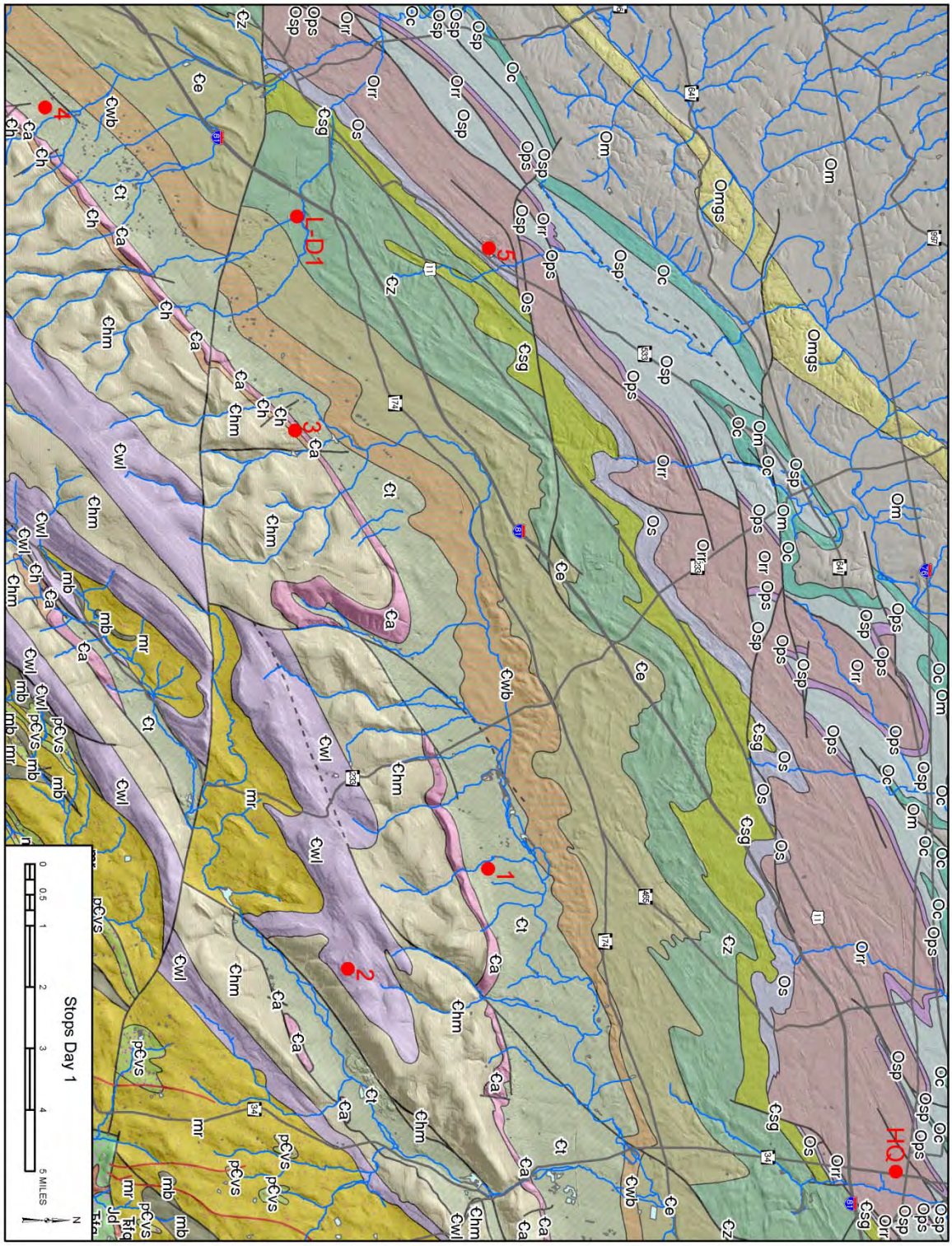

Day 1 Road Log. LiDAR image with Geologic Map showing Stops 1 – 5, Starting at Comfort Suites in Carlisle (HQ) & including Lunch Stop (L-D1)

Mileage Interval	Cumulative Mileage	**STOP = Stop Sign; = Traffic Light; "T" = T Intersection; TR = Township Route; "Y" = Y intersection**
0.0	0.0	Start at the Comfort Suites in Carlisle. Proceed south on South Hanover Street, passing 6 streets, some with traffic lights, until reaching West Willow Street.
0.4	0.4	At the ***turn right*** onto West Willow Street continuing straight until reaching the intersection of South West Street and the junction of Walnut Bottom Road.
0.3	0.7	At the ***turn half left*** onto Walnut Bottom Road; continue on Walnut Bottom Road for next **7.0** miles *Note: At mileage 1.1 houses to right, in karst depressions, living rooms were flooded during Hurricane Agnes in 1972*
0.9	1.6	I-81 Exit 45 underpass; **continue straight.** Over the next several route miles there are good views of South Mountain on the left, and of Blue (locally called North) Mountain on the right. *Note: From this point to cumulative mileage 8.9, no streams cross the route due to region's pervasive karst topography. Infrequent exposures are present along route to mile 7.6, stratigraphically downward they include the Ordovician Rockdale Run and Stonehenge formations, then Cambrian Shady Grove, Zullinger, and Elbrook formations.*
1.7	3.3	PA Route 465 joins Walnut Bottom Road from right. **Continue straight.**
4.4	7.7	At the junction of Walnut Bottom Road (PA Route 465) and PA Route 174-E ***turn left*** onto PA Route 174-E and then turn **immediately right** onto Montsera Road
0.5	8.2	At **"Y"** with Encks Mill Road, ***continue left*** to stay on Montsera Road
0.6	8.8	Cross railroad
0.1	8.9	Cross Yellow Breeches Creek
0.1	9.0	STOP ***turn right*** onto Pine Road *(to the left is Kings Gap General Store with excellent cheese wheel and 100 year old map of PA railroad routes)*
200 feet	9.0+	Take ***first left*** onto Kings Gap Road. *Note: sign for Kings Gap Environmental Education Center to left*
0.6	**9.6**	***ARRIVE*** **at Kings Gap Hollow pathway entrance to Kings Gap Pond – STOP 1**

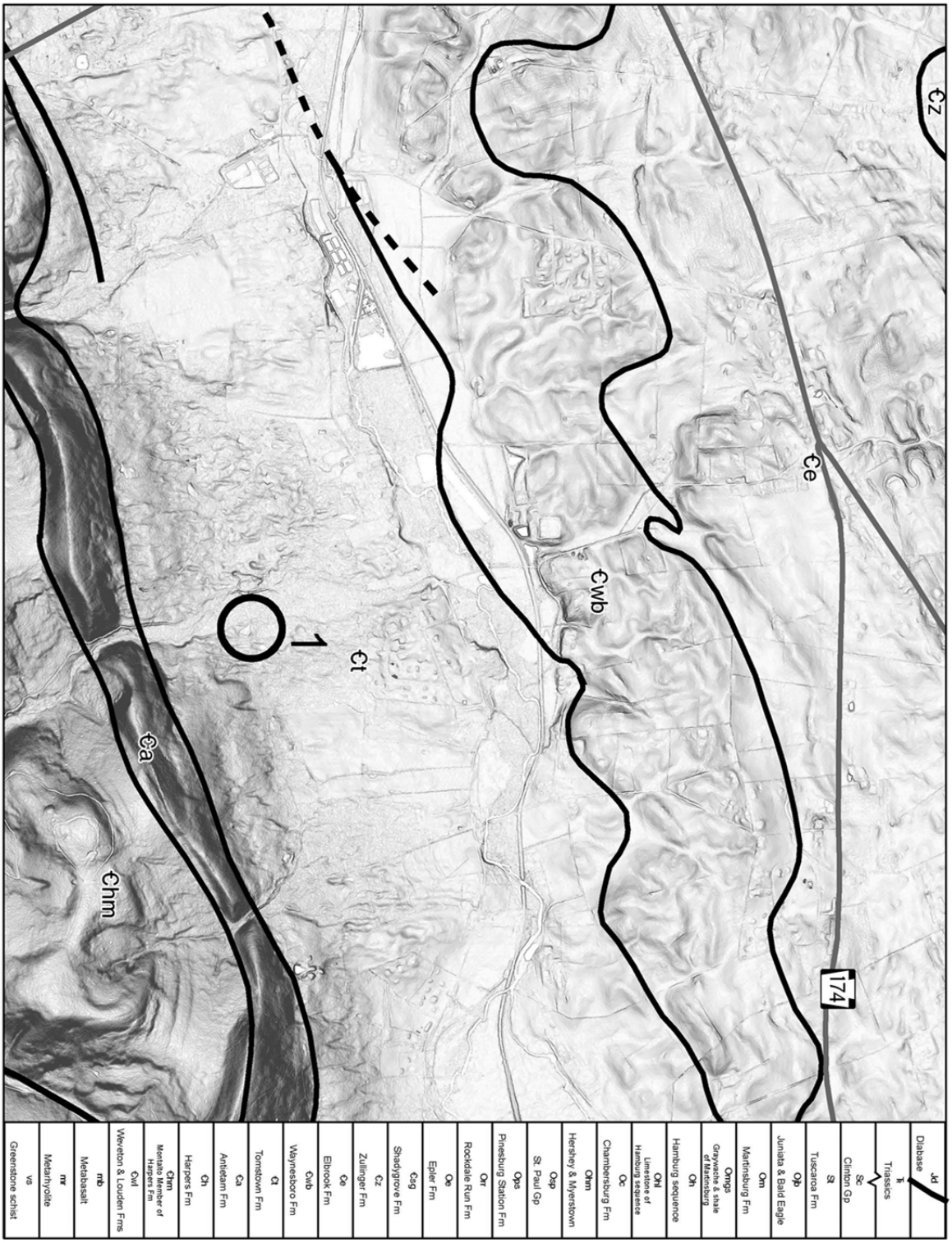

Figure 1. LiDAR image of Stop 1 – Kings Gap Pond area, with geologic contacts overlain

STOP #1 – KINGS GAP POND

Stop Leader Noel Potter, Jr., Dickinson College, Retired

Entrance to path accessing Kings Gap Pond

KINGS GAP POND, A WINDOW ON THE LATE PLEISTOCENE

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Introduction

Kings Gap Pond (KGP) (40°06'02.06" N, 77°18'46.79" W) (Fig 1 – LiDAR & Fig 2) is the largest of several vernal ponds at the northern base of South Mountain just east of the entrance road to Kings Gap Environmental Education Center. The pond is significant because of a sediment core obtained from it in 2001 with a basal date of 16,080 years BP. The portion of the core below a twig dated at approximately 14,000 BP contains fragments of tundra vegetation. Since the pond is at the base of South Mountain, the entire mountain must have been tundra in the Late Wisconsinan. In addition, just south of the pond, LiDAR (Fig 1) shows lobes that we interpret as solifluction lobes formed under cold conditions.

Access

Access the pond from opposite a log house along the paved Kings Gap road along a short (~100 m) walk along a dirt service road with a "No Parking" sign (Stop 1 entrance photo). Walk past the first spur to the right and keep going. At a second spur to the right, turn south at right angles to the road you've been walking on and follow an indistinct path up over a gentle rise to the pond (Fig 2).

Figure 2. Kings Gap Pond (January, 2008 photo) looking SE at moderate mid-winter depth. In a very wet spring the pond overflows an outlet behind the photographer. In a dry summer, the pond margin retreats well beyond the logs in water in the middle distance.

Geologic Setting

The steep north flank of South Mountain is about 0.5 km south of KGP (Figs. 3 and 4). This is underlain by the resistant Antietam sandstone of the Lower Cambrian Chilhowee Group. The gently sloping terrain northward from the base of the mountain to approximately Yellow Breeches Creek (top of Figs. 3 and 4) is underlain by the Cambrian Tomstown dolomite.

Figure 3. Orthophoto from PAMAP showing location of Kings Gap Pond (black triangle near left edge indicated by arrow). Compare to Fig. 4.

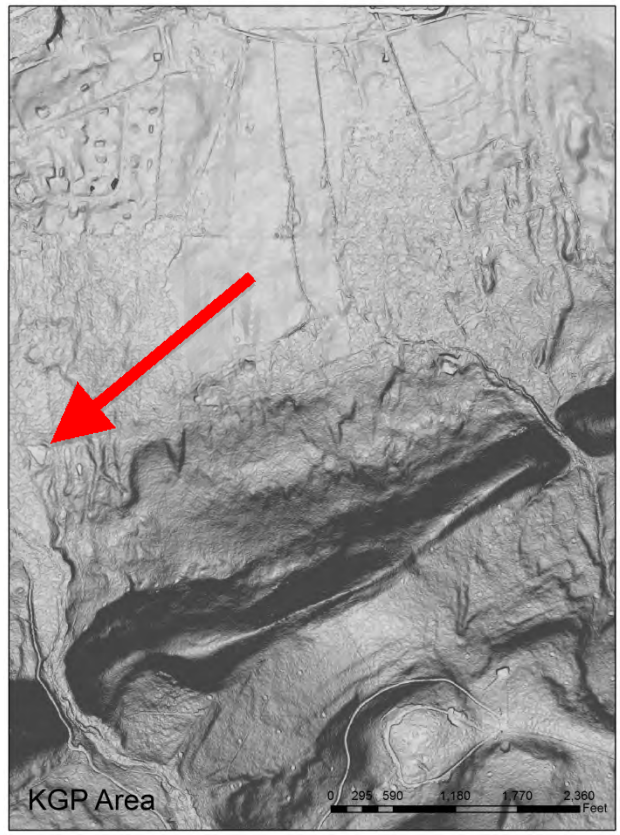


Figure 4. LiDAR Shaded Slope Map from PAMAP showing location of Kings Gap Pond (white triangle near left edge). Compare to Fig.3.

The Tomstown is rarely seen in outcrop because it is buried beneath a thick mantle of sandstone-rich colluvium and alluvium derived from South Mountain. This mantle is 1-4 km wide and extends the entire length of South Mountain in Pennsylvania and farther south into the Shenandoah Valley in Maryland and Virginia (Fig. 5). Depth to bedrock near KGP is >30 m, as obtained from records for nearby water wells. Elsewhere depths to bedrock are as much as 125 m.

Vernal Ponds

KGP is one of hundreds of vernal ponds on top of the colluvium/alluvium at the NW base of South Mountain. The water level in vernal ponds fluctuates significantly with the seasons. In late fall and winter KGP fills so that it is a meter or more deep, most years reaching maximum depth in spring. During summer water levels go down due to drainage and evaporation, and in some very dry years KGP becomes a small mud hole near its NE corner (Fig. 2). We have never seen KGP totally dry.

KGP and other vernal ponds at the base of South Mountain formed as karst depressions in the colluvium/alluvium due to long-term solution of the underlying Tomstown dolomite. The ponds are important habitat for several species of salamanders and toads, which migrate to the ponds to breed (Wingert, 2001).

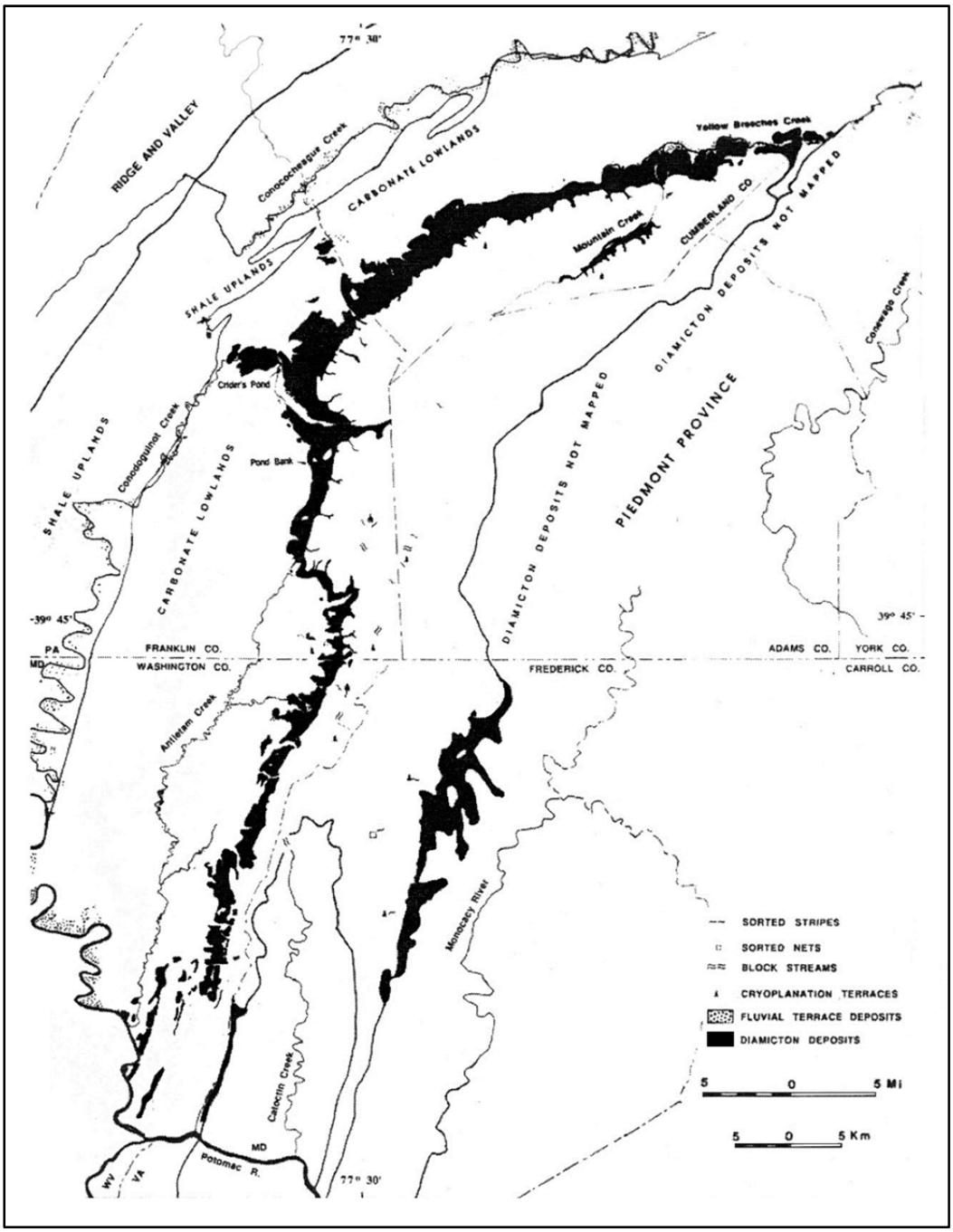


Figure 5. Black area shows distribution of colluvial apron along the west side of South Mountain (from Clark, 1991, Figure 13, p. 61).

Pond Sediment

The sediment in one of these vernal ponds, Crider's Pond (now named Mountain Run Pond), about 20 km SW of here and SW of Shippensburg, was cored in the 1970's, and Watts (1979) published pollen and plant macrofossil diagrams from it. The core there had a basal date of about 14,000 years BP, and the dominant vegetation then was spruce, followed by pine, then hardwoods to the present.

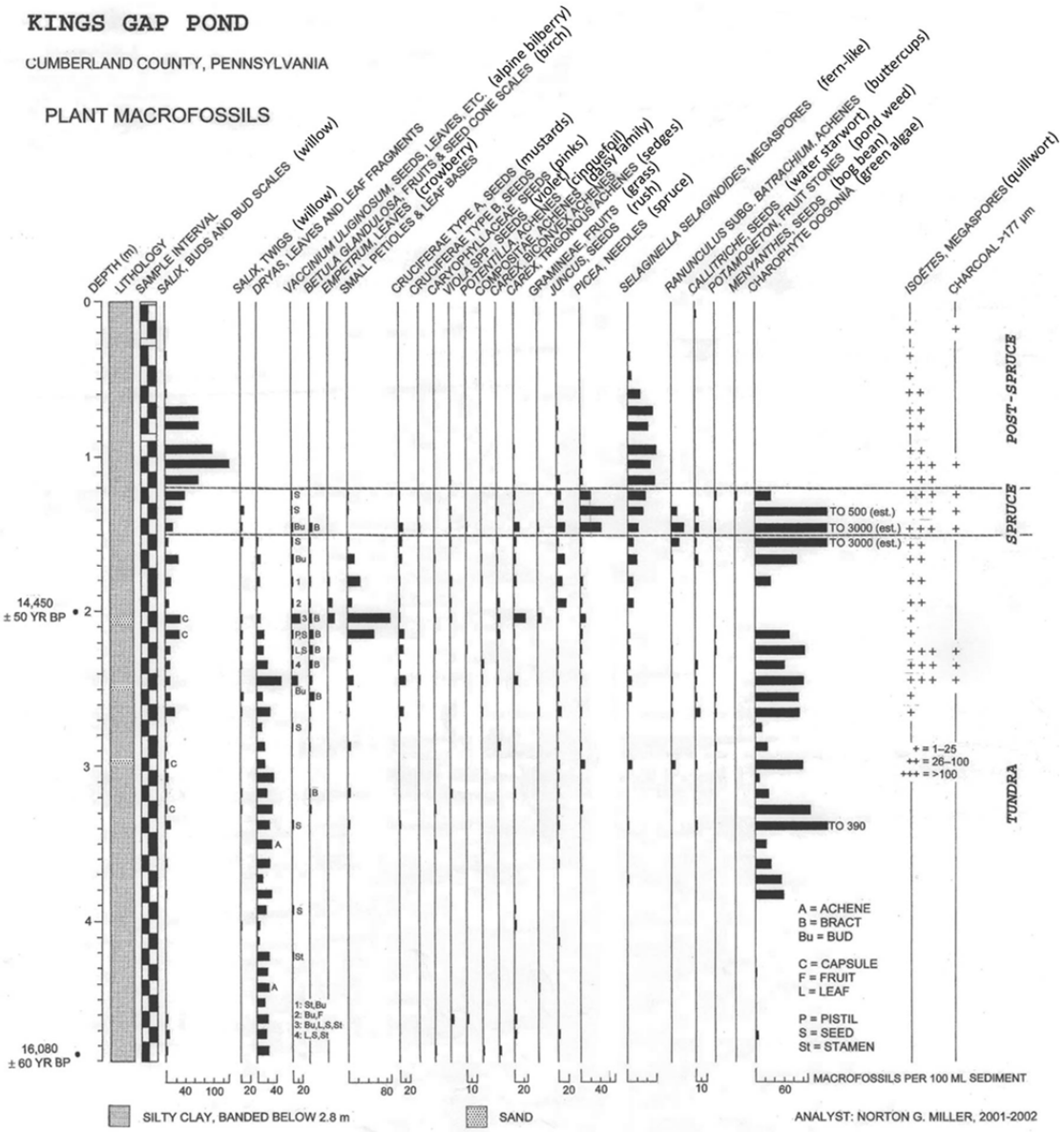
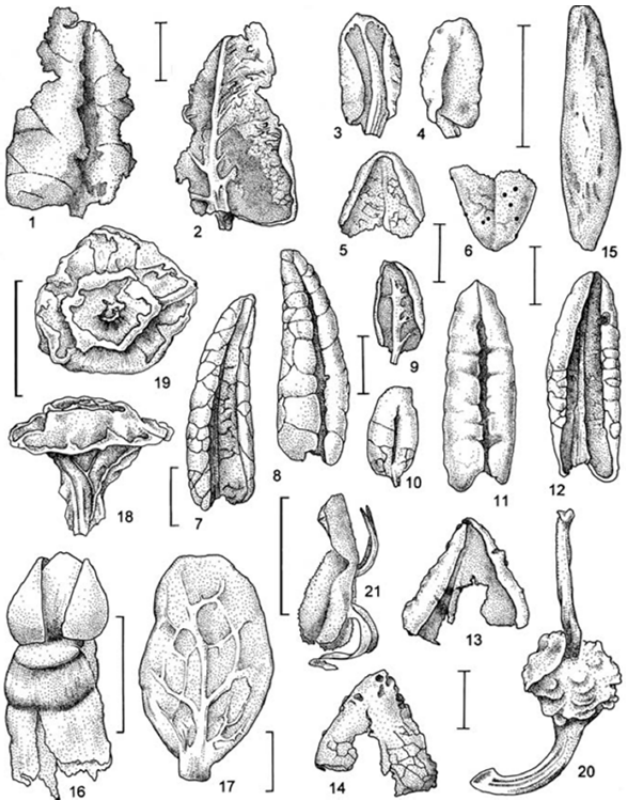


Figure 6. Norton Miller's Plant Macrofossil Diagram for Kings Gap Pond. Note two C-14 dates along the left side, and plant zones along the right side.

KGP Sediment Core

In January, 2001 Noel Potter, Bill Sevon, Helen Delano, and a cast of helpers cored KGP through ice and obtained a core just short of 5 m long (Delano and Potter, 2001; Delano, et al., 2002). We obtained a basal radiocarbon date on the core of 16,080 years BP and a date about half-way up of 14,450 years BP (Fig. 6). The sediment was alternating layers of silty clay and sand, with sand less abundant in the top meter. Norton Miller, of the New York Biological Survey, studied the plant macrofossils (Fig. 6) from the KGP core and found the dominant vegetation from the base to a bit above the 14,450 year date to be tundra vegetation. The key indicator is *Dryas arctifolia*, a classic and distinctive tundra plant, along with dwarf birch, also common on tundra. A spruce zone, then post-spruce shrubs and other plants follow the tundra zone up the core to the present. Several people attempted to examine pollen from the core, but recoverable pollen grains were too sparse for useful analysis. Pine and hardwoods might have been identifiable by pollen, but were probably present based on the other plants that are identified in the upper zone. The uppermost 1 m of sediment is bioturbated. Think of the vegetation one would traverse traveling from northern Hudson's Bay to our hardwood forests here. As one moves south to warmer climates one would leave the tundra and go to spruce forests, then to pine forests, then to mixed pine and hardwood



1–15, Mountain Avens (*Dryas integrifolia*),

1–14, partial and complete leaves of different size and preservation characteristics, black dots in 6 are fungus fruiting bodies,

15, fruit (achene), style broken off;

16–21, Alpine Bilberry (*Vaccinium uliginosum*),

16, twig and terminal bud,

17, leaf,

18, **19**, receptacle and gynoecium (different aspects of same fossil), **20**, pedicel, gynoecium, style (portion of perianth on top of gynoecium at left),

21, stamen;

All scale bars 1 mm.

Figure 7A. Illustrations of plant macrofossils from the Kings Gap Pond core by Patricia Kernan, New York Biological Survey.

such as one would find in the Adirondacks and northern New England, and finally to the hardwoods we have in Pennsylvania. These vegetation changes are a measure of climate change here since the Late Wisconsinan. Figures 7A and 7B are illustrations of some of the plant macrofossils from the KGP core.

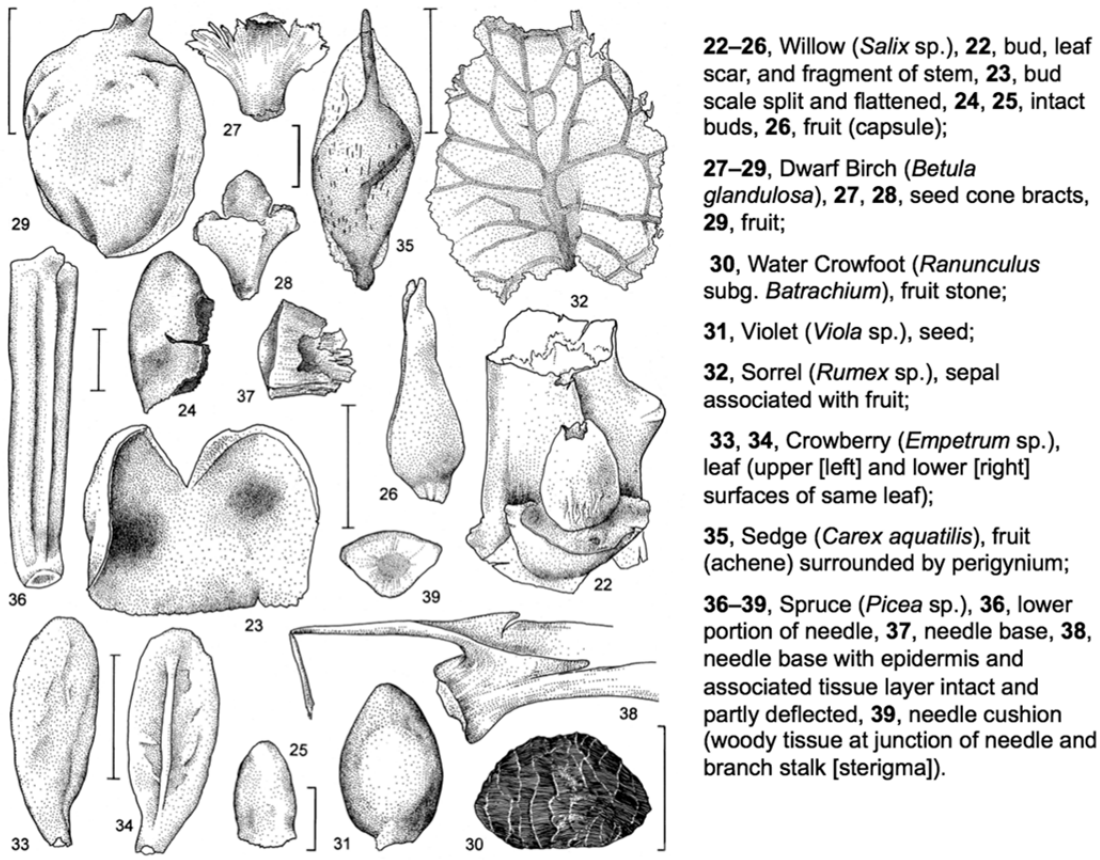


Figure 7B. Illustrations of plant macrofossils from the Kings Gap Pond core by Patricia Kernan, New York Biological Survey.

It is interesting to note that the lower half of the core represents only about 2,000 years, whereas the upper half covers roughly 14,000 years. This probably means that the whole Holocene is represented by less than the top meter of sediment. David Cruz, a Dickinson College student, recently performed loss on ignition (LOI) on the KGP core (Fig. 8) and shows that all but the topmost part of the core is low in organics. The fact that the sedimentation rate was considerably higher in the Late Wisconsinan may be related to the presence of gelifluction lobes just to the south (see below). The significance of the tundra vegetation during the Late Glacial at this site at the base of South Mountain, means that locally the top of South Mountain would also have been tundra. This strengthens the case that bedrock knobs like Hammonds Rocks (Day 1, Stop 2) are tors.

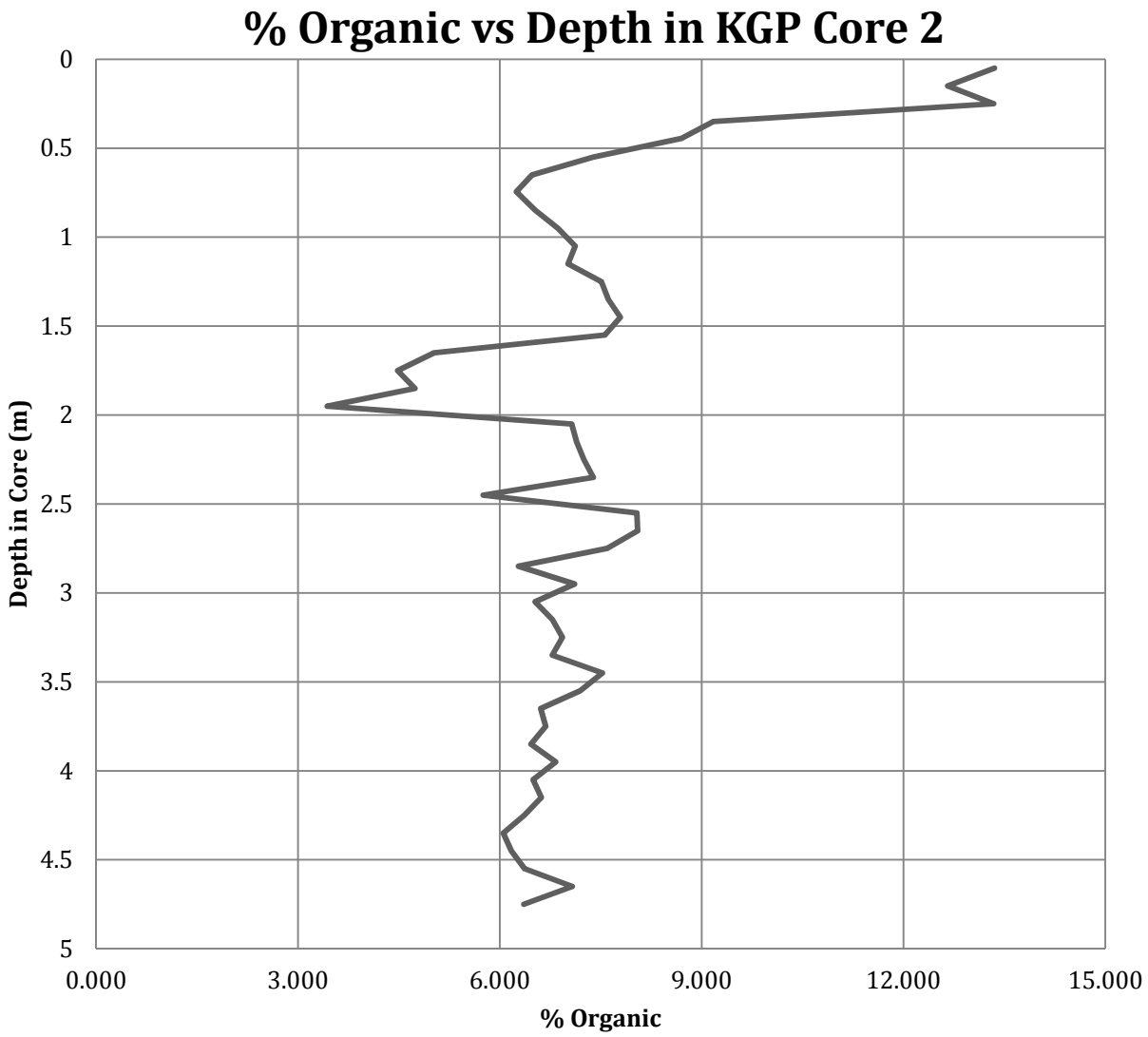


Figure 8. Loss on ignition in Kings Gap Pond Core. Analysis by David Cruz, Dickinson College.

Following page:

Figure 9. Kings Gap Core – Graphic Log
The length of total recovered core and of each section are shown graphically along the left side.
Sediment texture is shown by the width of the bar (scale above each column). Determinations were by visual inspection of the cut surfaces with the aid of a binocular microscope
Colors are approximately those shown.
Relative abundance of minute (<1mm) organic fragments is shown by letters along the left side of the bar. VS-Very sparse, S-sparse, C- Common, A- Abundant, VA- Very abundant. Range of abundance in banded or mottled units is shown with minimum and maximum as S/A (sparse to abundant).
Other features noted in the core are indicated by single letters in the bar. These include O-larger organic fragments, leaves and twigs, P – quartzite pebbles, most 1 to 2 cm diam., V – Vivianite blebs, most < 1mm, some to 1.5 cm.
Sample locations for two AMS radiocarbon dates are shown by red stars.

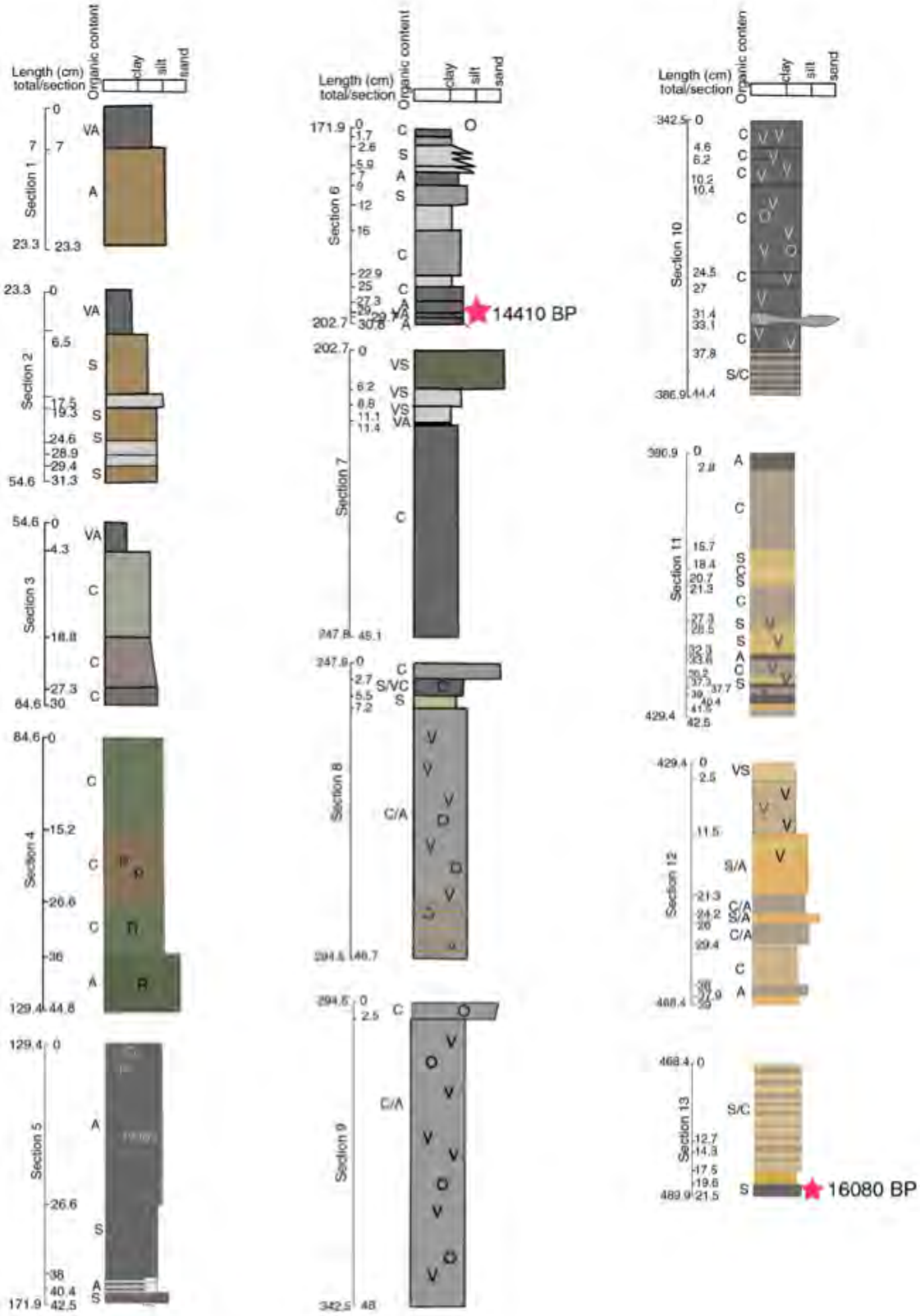


Figure 9. Kings Gap Core – Graphic Log

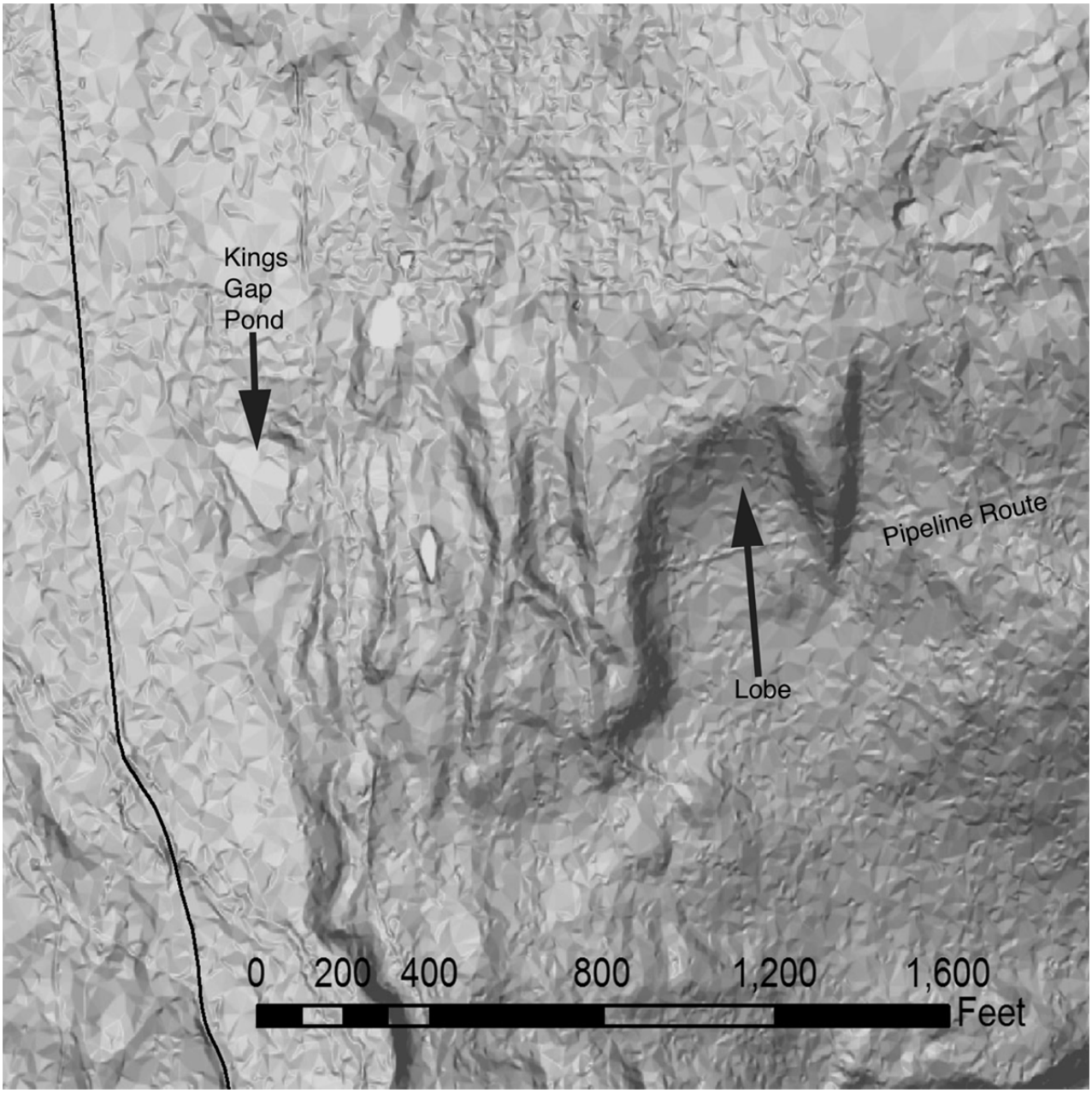


Figure 10. Detailed LIDAR Shaded Slope Map of Stop 1 area

Lobate Features South and East of KGP

A prominent lobe and steep front occurs about 250 m E of KGP *(Fig. 10).* The steep front is about 10 m high, and to the S of this front topography is subdued compared to N of it *(Fig. 10).* Similar lobes occur farther to the East *(Fig. 4)* and elsewhere on the North flank of South Mountain. The material in the lobe is bouldery colluvium with abundant clasts of sandstone derived from steep slopes on the near-vertical Antietam sandstone just to the south.

We interpret these lobes as solifluction or gelifluction lobes that moved northward from South Mountain under periglacial conditions during the Late Wisconsinan. These features are not active in our present climate. The lobes are almost perfect replicas of periglacial gelifluction lobes and sheets, ubiquitous in arctic and alpine regions today. These features generally move a few centimeters a year.

Figure 11 shows classic lobes and sheets in Alaska. Discussions of similar features can be found in Benedict (1976), Matsuoka (2001), and French (2007, especially Chapter 9). These features generally move a few centimeters a year.

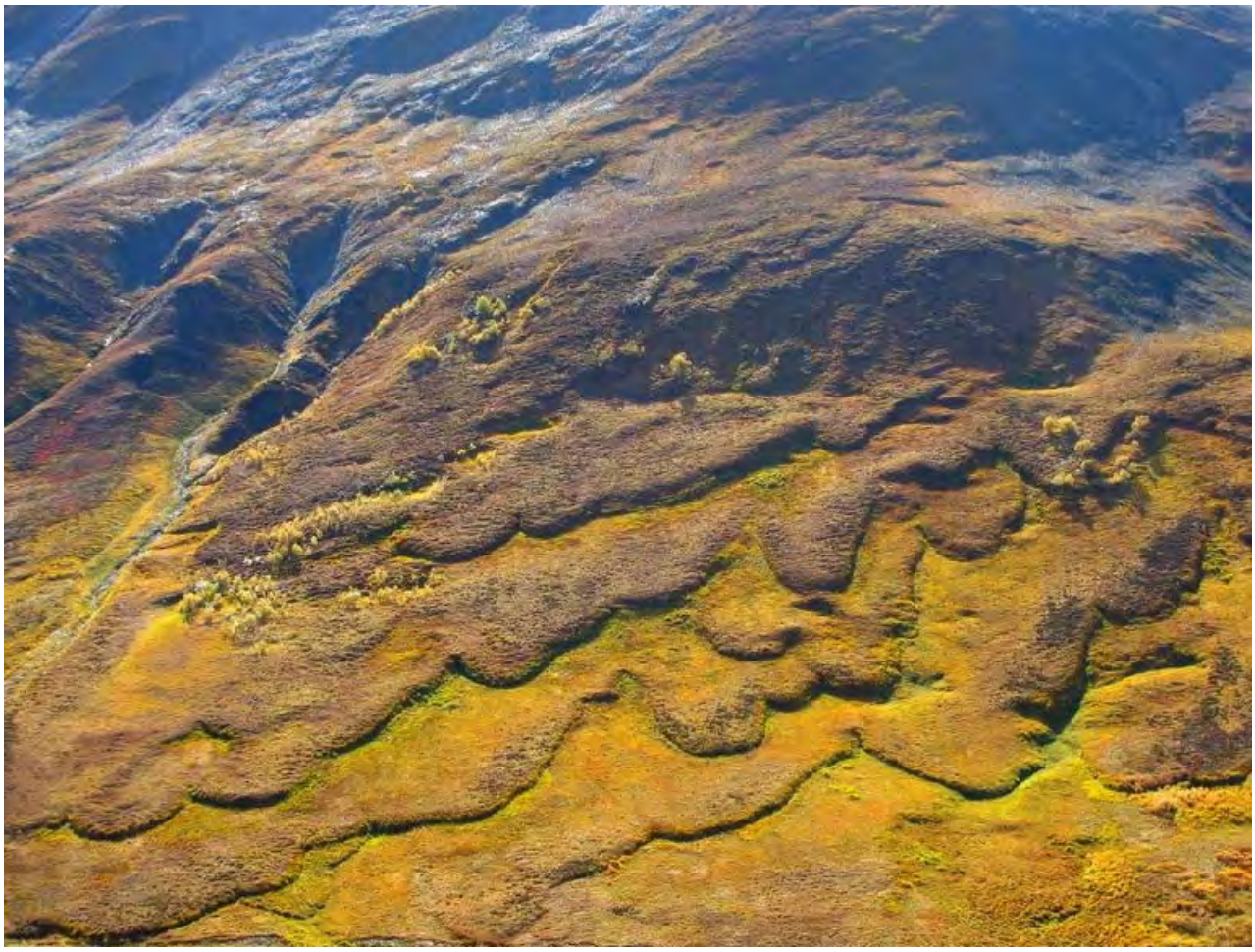


Figure 11. Gelifluction sheets and lobes in Alaska. Ed Plumb photo at: http://edplumb.blogspot.com.

Solifluction vs. Gelifluction?

Solifluction, "the slow viscous flow of waterlogged soil and other unsorted and saturated surficial material" (Neuendorf, et al., 2005) is the more generic term and may or may not involve frozen ground. Gelifluction occurs over frozen ground. The frozen ground may be deep annual frost or permanently frozen ground (permafrost). Clearly, frozen ground is highly conducive to downslope movement of overlying soil, for the thawed active layer in summer remains saturated because downward movement of water is impeded by ice.

Thus we ask—was there permafrost here on and near South Mountain? Clark (1991) and Ciolkosz, et al. (1986) catalog an abundance of periglacial features on South Mountain, including sorted stone stripes, small block fields, and tors, but none of these requires permafrost—merely cold periglacial conditions. Tundra vegetation from the KGP core could have existed on permafrost, but can also grow where there is only deep annual frost. The higher sedimentation rate in KGP during the Late Wisconsinan is not surprising given the cold conditions and intermittent surface thaw inferred from the lobes just to the south. Gelifluction can occur in deep annual frost. The best indicator of permafrost is ice-wedge casts, for the ground must be permanently frozen for ice-wedges to develop. Ice-wedge casts have been described from the Pine Barrens of southern New Jersey and in the northern Delmarva Peninsula (French, et al., 2003; French, 2007). A map by French (2007) showing reconstruction of the maximum extent of Late Pleistocene periglacial conditions in the USA south of maximum glaciation limits shows the southern limit of "continuous and discontinuous permafrost" crossing the northern part of Chesapeake Bay into Virginia and West Virginia. Marsh (1987) described pingo scars in Union County to the north, and pingos require permafrost to form. We cannot say from local evidence that there was permafrost on and near South Mountain, but the evidence from adjacent areas says it likely was here.

Karst from the Lobate Features Northward

North of the lobate features, including KGP and the area we traversed to get to the lobe, topography is much more hummocky *(Fig. 1)*, typical of karst. This topography persists, with abundant sandstone clasts at the surface, all the way north to the floodplain of Yellow Breeches Creek near Pine Road. We infer that this surface is much older than the lobes because it is modified by karst, and it is clear that at least in the case of KGP, the bottom has not sunk significantly in the last 16K years. Are these older colluvial deposits also of periglacial origin, but much older, or are they simply coarse sediment carried out of the streams that drain from South Mountain? We will re-visit this question at Stop 4, where we will see a deep pit into the colluvial material.

References

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

Benedict, J. B., 1976, Frost creep and gelifluction features: a review: Quaternary Research, v. 6, p. 55-76.

Ciolkosz, E. J., Cronce, R. C., and Sevon, W. D., 1986, Periglacial features in Pennsylvania: Pennsylvania State University, Agronomy Series, No. 92.

Clark, G. M., 1991, South Mountain geomorphology: *in* Sevon, W. D. and Potter, N., Jr., *eds.*, Geology in the South Mountain area, Pennsylvania: Guidebook for the 56th Annual Field Conference of Pennsylvania Geologists, p. 55-94.

Delano, H. and Potter, N., 2001, Kings Gap Pond: *in* Potter, N., Jr., *editor*, The Geomorphic evolution of the Great Valley near Carlisle, Pennsylvania: Guidebook, Southeast Friends of the Pleistocene, 2001 Annual Meeting, Carlisle, PA, p. 111-119.

Delano, H. L., Miller, N. G., Potter, N., Jr., 2002, Plant fossil evidence for late Pleistocene tundra conditions in south-central Pennsylvania: Geological Society of America, Northeastern Section, 37th Annual Meeting, Abstracts with Programs, v. 34, no. 1, p. 27.

French, H. M., Demitroff, M., and Forman, S. L., 2003, Evidence for Late-Pleistocene permafrost in the New jersey Pine Barrens (latitude 39°N) eastern USA: Permafrost and Periglacial Processes, v. 14, p. 259-274.

French, H. M., 2007, The periglacial environment, 3rd edition: John Wiley & Sons, Chichester, England, 458 p.

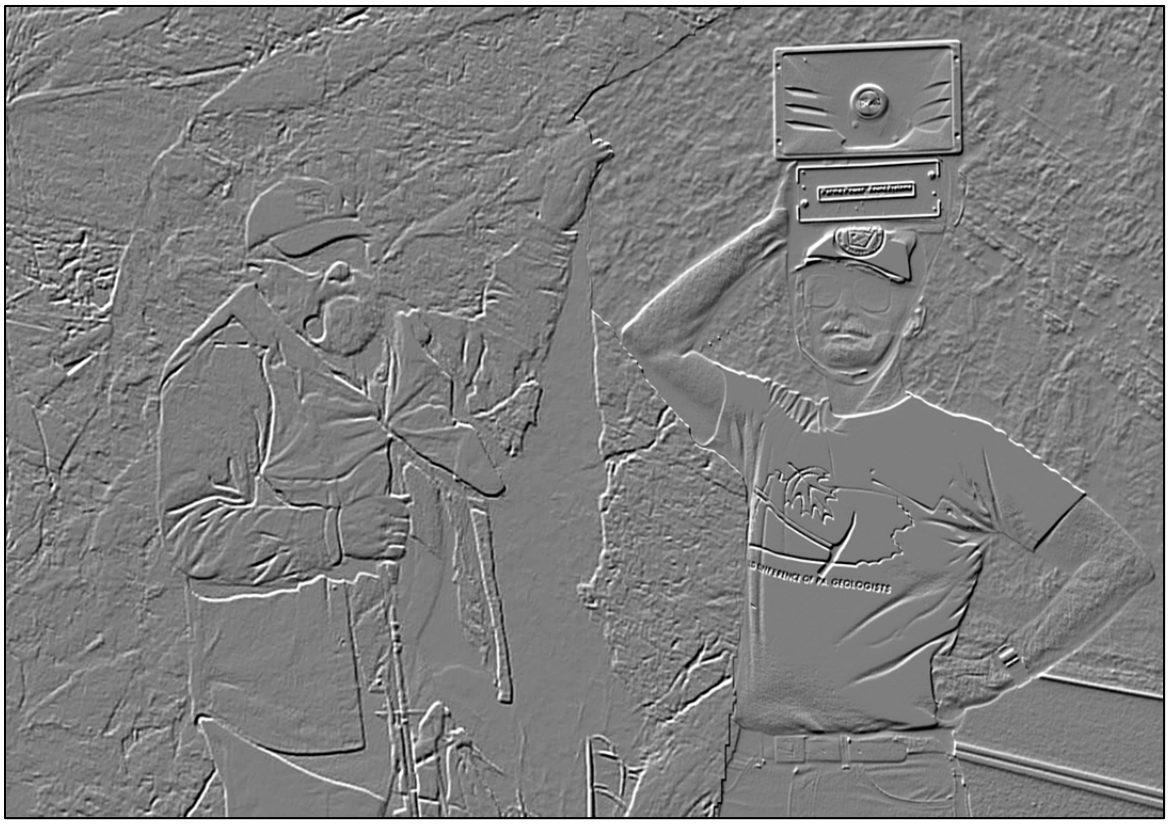
Marsh, Ben, 1987, Pleistocene pingo scars in Pennsylvania: Geology, v. 15, no. 10, p. 945-947.

Matsuoka, N., 2001, Solifluction rates, processes and landforms: a global review: Earth Science Reviews, v. 55, p. 107-134.

Neuendorf, K. K. E., et al., 2005, Glossary of Geology, 5th edition: American Geological Institute, Alexandria, VA.

Watts, W. A., 1979, Late Quaternary vegetation of central Appalachia and the New Jersey coastal plain: Ecological Monographs, v. 49, p. 427-469.

Wingert, H. Eugene, 2001, Life in a Vernal Pond: Keystone Outdoors, March/April issue, p. 28-31.

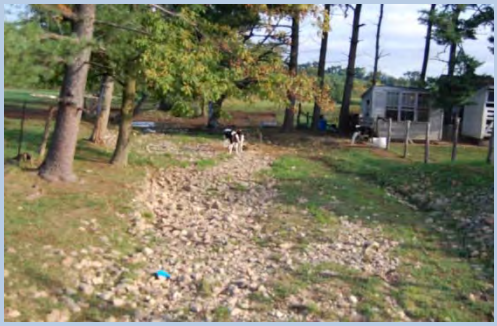


LiDAR slopeshade image of two unique geologic features showing underlying structure and Holocene weathering effects.

Mileage Interval	Cumulative Mileage	**STOP = Stop Sign; = Traffic Light; "T" = T Intersection; TR = Township Route; "Y" = Y intersection**
0.0	9.6	Return north to Pine Road
0.6	10.2	STOP ***Turn left*** on Pine Road (TR 3006)
1.3	11.5	Cross Lebo Road; PA Fish Commission Huntsdale hatchery to right
0.9	12.4	STOP **Turn Left** onto PA Route 233 (Centerville Road) *Note: the stream immediately prior to the intersection and diagonally crossing Centerville Road is ephemeral; during periods of low flow the stream's water infiltrates into stream bed colluvium derived from South Mountain (ahead) that mantles the underlying karstic carbonates.*

Ephemeral stream at PA 233 and Pine Road, looking downstream

during minor flood on May 12, 2008



during dry period on September 19, 2008

(Photos by Noel Potter)

1.0	13.4	At the south border of Mt. Ashbury Camp (right) is the mapped contact and topographic rise signifying the contact of sandstones of South Mountain with carbonates of the Great Valley.
2.4	15.8	**Turn left** onto Ridge Road; road is gravel and dirt
2.0	17.8	Cross Cold Springs Road; continue straight
0.7	**18.5**	***ARRIVE* at Hammonds Rocks – STOP 2**

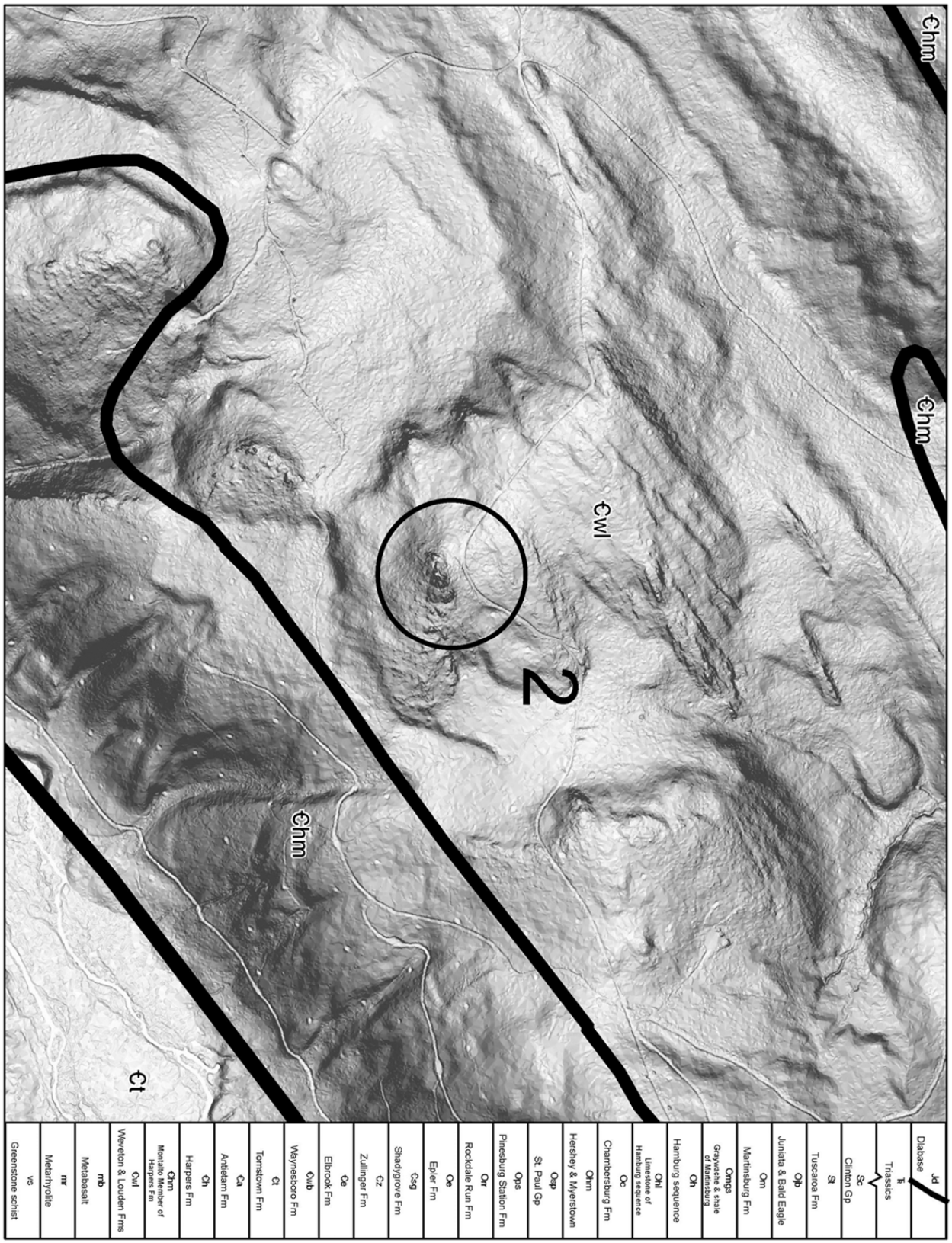


Figure 1. LiDAR image of Stop 2 – Hammonds Rocks area, with geologic contacts overlain

STOP # 2 – HAMMONDS ROCKS

Stop Leader – Noel Potter, Jr.

Entrance path to Hammonds Rocks, a Tor

HAMMONDS ROCKS, SOUTH MOUNTAIN, CUMBERLAND COUNTY, PENNSYLVANIA

Noel Potter, Jr., Department of Earth Sciences (retired), Dickinson College, Carlisle, PA 17013, pottern@dickinson.edu

Introduction and Location

Hammonds Rocks (HR) (40°05'04.44" N, 77°14'56" W) is a prominent knob on the crest of South Mountain made of sandstone and conglomerate that protrudes above bouldery surfaces that gently slope away from it (Fig. 1 – LiDAR). The in-place core of HR nicely demonstrates how the pebbles in the conglomerate were deformed during the Alleghanian. Very large blocks that broke away from the core and lobate features (Fig. 1) that formed east of the rock knob attest to a periglacial climate during the Pleistocene. HR is on the crest of South Mountain (see Stop 2 entrance photo, above) on the south side of Ridge Road 0.7 mi east of Cold Spring Road. It is in the Mount Holly Springs 15' Quadrangle mapped by Freedman (1967).

Stratigraphy

HR (most detailed description is in Potter, et al., 1991) is composed of the Weverton formation, which is mostly sandstone, but some of the rocks here are conglomeratic. Typically pebbles are 2-5 cm long (Fig. 2), but at least one is 12 cm long.

Figure 2. Pebbles flattened in the plane of cleavage, which dips downward to the right (SE). View is looking NE. Divisions on scale are in decimeters.

The Weverton is the next to bottom-most formation of the Lower Cambrian Chilhowee group clastic rocks (which overlies the bottom-most Loudon formation, which in turn overlies Precambrian metavolcanics) (see Key, 1991). Source for the Weverton formation was from the West on the North American craton, as determined by Whitaker (1955), in contrast to younger Paleozoic clastic rocks north of the Cumberland Valley whose sources were from the East (Fig. 3).

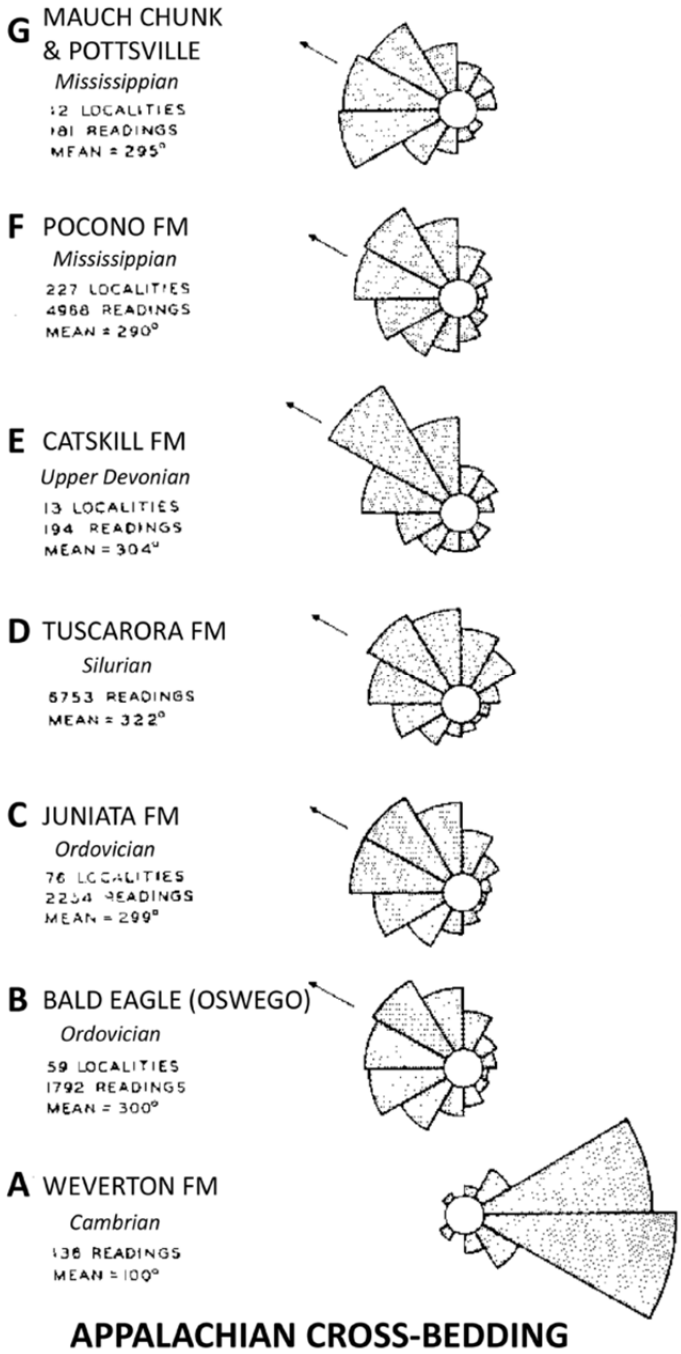


Figure 3.
Paleocurrent directions showing how Cambrian Weverton formation is derived from West, whereas later Paleozoic sediments are derived from East. (after Pettijohn, 1962).

Structure

Discretion is needed in examining the structure. Many large (up to several m long) blocks have been tilted and moved away from the core outcrop by frost during the Pleistocene. In many places in the outcrop cleavage, which dips SE, is more prominent than bedding, so one has to be careful to find compositional differences, usually pebbly layers, to make sure one is seeing bedding. Bedding is near vertical to slightly overturned in most of the outcrop (Fig. 4, Net A), but in a few places beds dip gently East, forming a girdle that shows a fold hinge that gently plunges ~N70°E. Cleavage consistently dips ~60°SE (Fig. 4, Net B). A plot of bedding/cleavage intersections (Fig. 4, Net C) shows that they trend ~N70°E, 10°NE.

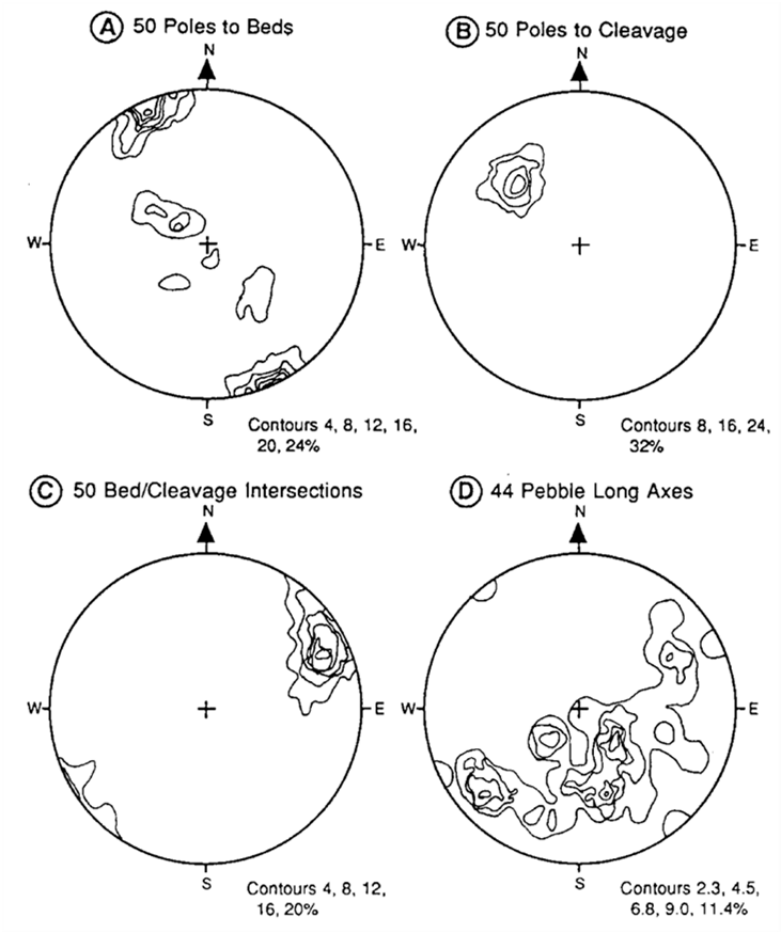


Figure 4. Equal-area nets showing orientation of: A) bedding, B) cleavage, C) bedding/cleavage intersections, and D) pebble long axes at Hammonds Rocks. (from Potter, et al., 1991, STOP 8)

Deformed Pebbles

Pebbles in the conglomerate are flattened so that their shortest axes are nearly perpendicular to cleavage (Fig. 2). Long axes of these flattened pebbles form a diffuse girdle with the same orientation as cleavage (Fig. 4, Net D), showing that though the short axes of pebbles are nearly perpendicular to cleavage, long axes lie in any direction near parallel to the plane of cleavage. We collected 350+ loose pebbles that had weathered out of HR and measured their 3 axes and plotted their axial ratios on Flinn diagrams (Potter, et al., 1991, Fig. 64). By far, more were oblate spheroids (hamburgers) rather than prolate (hot dogs).

We applied the Rf/Phi technique (Lisle, 1985) in 5 in-situ exposures (A through E on Figure 6) to determine strain in a plane perpendicular to cleavage and fold axes—that is in a near-vertical plane trending about N20°W. At the five sites the strain ration varied between 1.9 and 2.5 (mean 2.1) (Potter, et al., 1991).

At another outcrop of the Weverton conglomerate at Whiskey Spring, 9 mi E of Hammonds Rocks we discovered striae on many of the pebbles (Potter, et al., 1995), and since then we have found them here at HR.. Surfaces on the pebbles that are parallel to cleavage often have very fine striae on them. These striae are always parallel

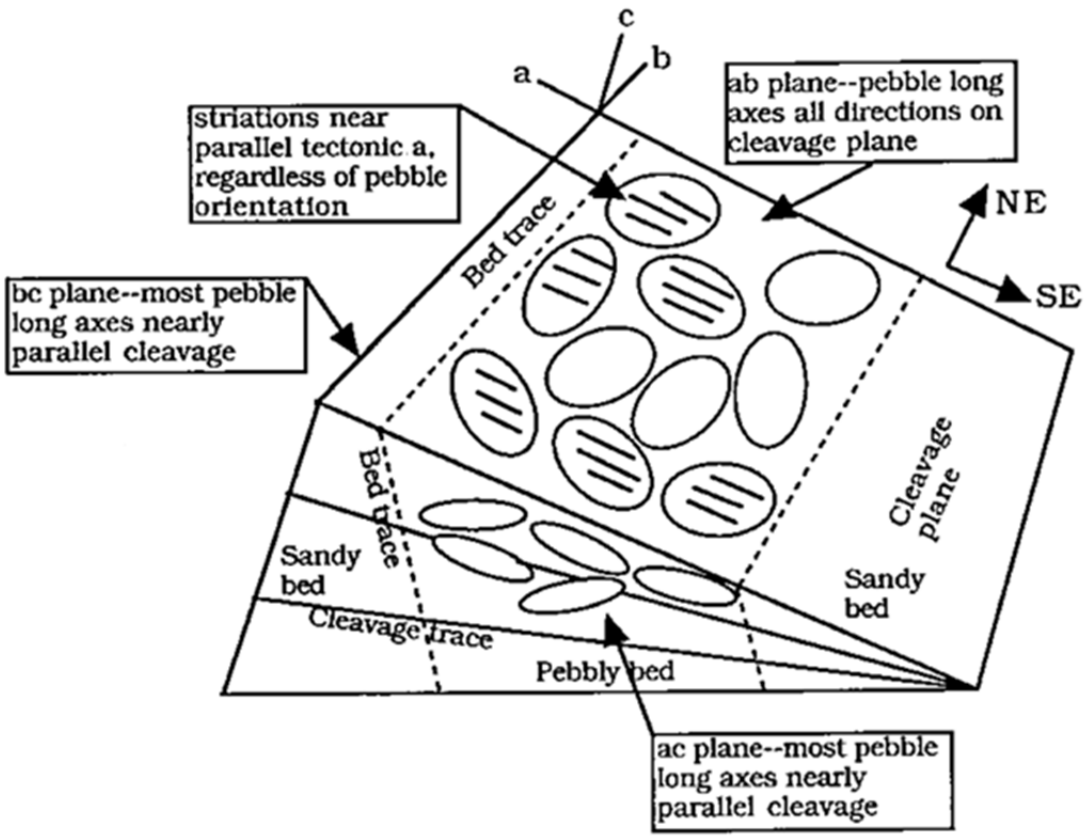


Figure 5. Relation of flattened pebbles and striations to bedding and cleavage at Hammonds Rocks. (Diagram from Potter, et al., 1995)

to tectonic a, the direction of tectonic transport, and perpendicular to bedding-cleavage intersections, despite random orientation of long axes of pebbles in or nearly parallel the plane of cleavage (Fig. 5). A hand lens and a strong flashlight (or mirror using the sun) to give low oblique illumination are best for seeing the striae. It is inferred that shear parallel to cleavage removed the "tops and bottoms" of the pebbles by pressure solution. Thin sections show fine quartz as “tails” to the pebbles.

We attempted to determine paleocurrent direction using cross-beds here, but in nearly all cases when we measured inferred topset and foreset beds and plotted them on a stereonet, the angle between the two was much greater than the angle of repose for sand—presumably the angle between the two has been changed during deformation.

At the Outcrop

A map and series of cross-sections of HR prepared in 1991 are reproduced as Figs. 6 and 7. The map of HR (Fig. 6) has a number of stations labeled with Roman numerals. A series of cross sections (Fig. 7) along lines labeled with Arabic numbers are also reproduced here. Highlights of some Roman Numeral stations from the map are:

I) a prominent channel with lag gravel in it. This is one of the few places where beds are horizontal in the outcrops here. It is an interesting place to ask where one would go to find a similar environment of deposition today. Remember that there was no land vegetation in the Cambrian.

II) good cross beds at the E end of the outcrop.

III) a good view of pebbles flattened in cleavage.

IV) If you crawl under the large (several m long and high) block here, you can find three irregularly spaced quartz veins in the block above and the rock below to see that the large block has moved about 1 m downslope. Note on cross-sections several large blocks with cleavage dipping the wrong way (N rather than SE).

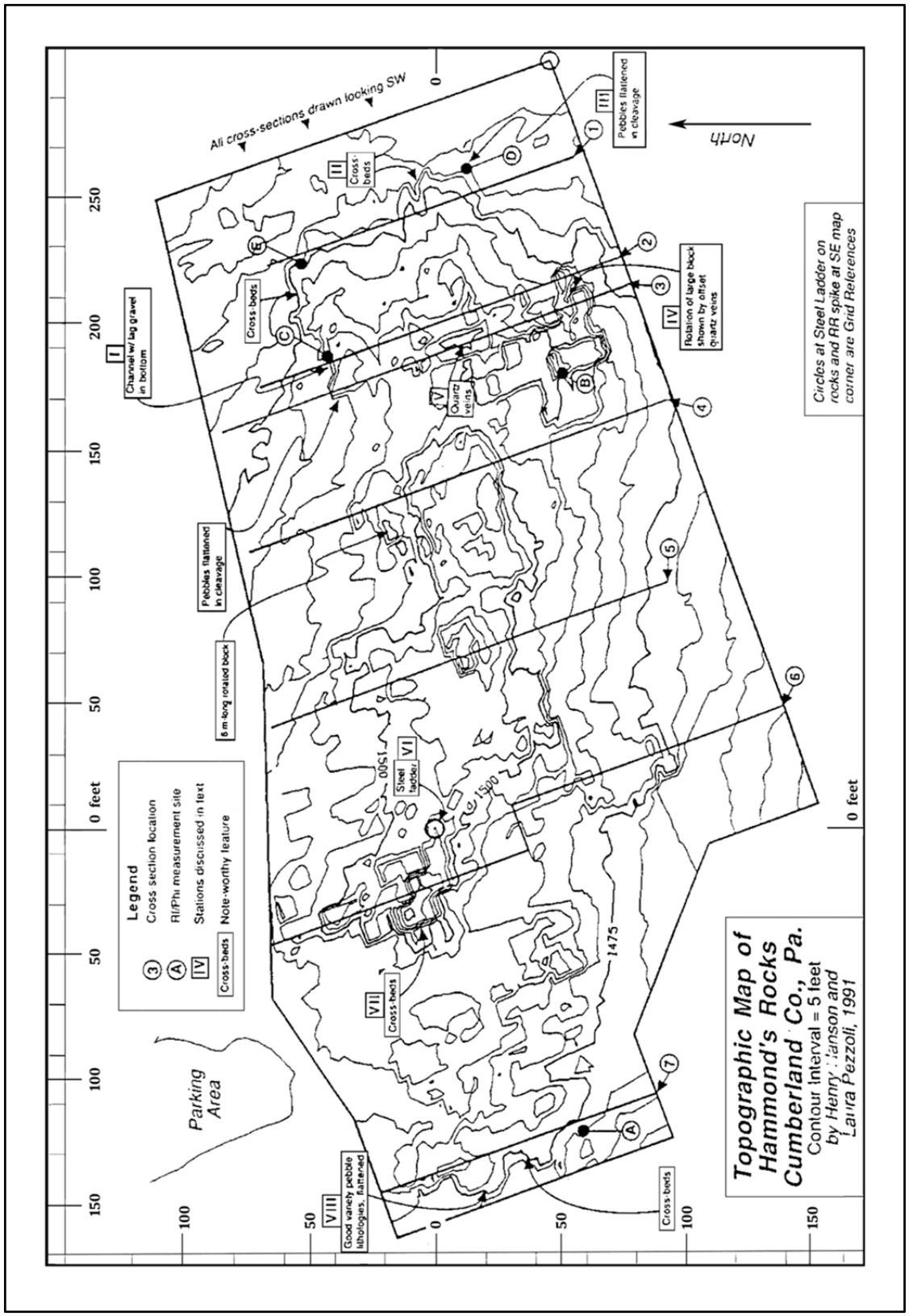


Figure 6. Topographic map of Hammonds Rocks showing locations of cross sections (Fig. 7) and features described in text. From Potter, et al., 1991, STOP 8.

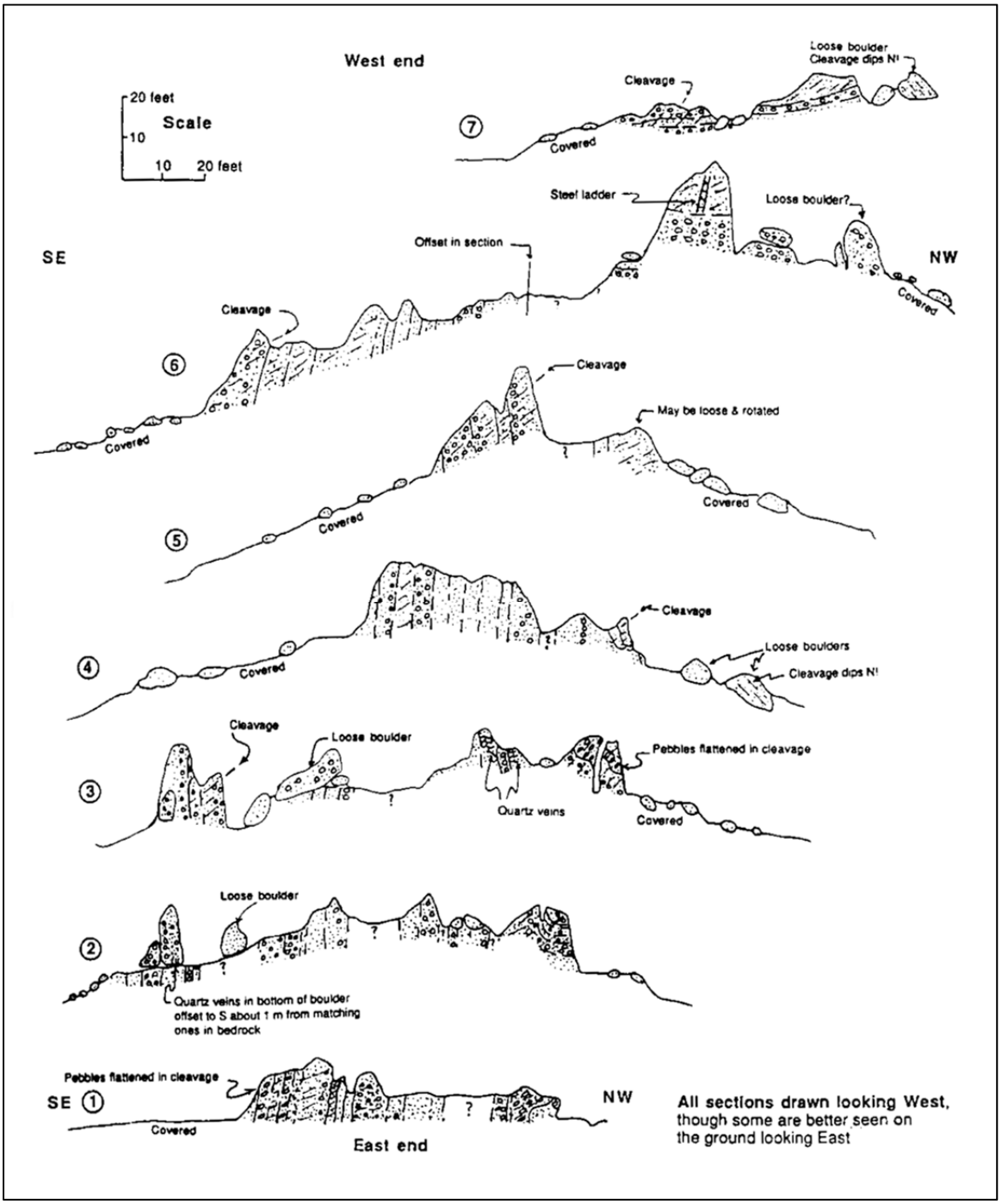


Figure 7. Cross sections of Hammonds Rocks. All sections are drawn looing WEST for ease of comparison, despite the fact that some are better seen at the outcrop looking in the opposite direction. Locations of sections are on Figure 6. From Potter, et al., 1991, STOP 8.

Periglacial Features

HR has been interpreted by Clark (1991) as a tor, a prominent erosional remnant that sticks up above an otherwise gently-sloping surface that is inferred to have formed in a periglacial climate during the colder parts of the Pleistocene. Other similar knobs occur to the south and north of HR (Fig. 1). A modern tor in Alaska is shown in Figure 8. We know that during the late Wisconsinan, from at least 16,000 to 14,000 years BP, there was tundra here (Delano, et al., 2002; see Stop 1—Kings Gap Pond this volume).

Figure 8. A modern tor in Alaska. Note gently sloping surface covered with boulders at base of bedrock knob.

We have already remarked on the large tilted blocks next to the core of HR. Since cleavage consistently dips SE in true bedrock, any blocks with cleavage dipping in other directions are "out of place." It is clear that none of the large blocks are moving today, so we interpret the movement of the large blocks as the result of periglacial conditions during the Pleistocene.

To the East of HR are two prominent lobes (Fig. 9) that have moved downslope to the East. The large blocks in these lobes have cleavage dipping in random directions, clearly showing that they are not in place. We interpret these lobes to have formed by gelifluction during the cold phases of the Pleistocene.

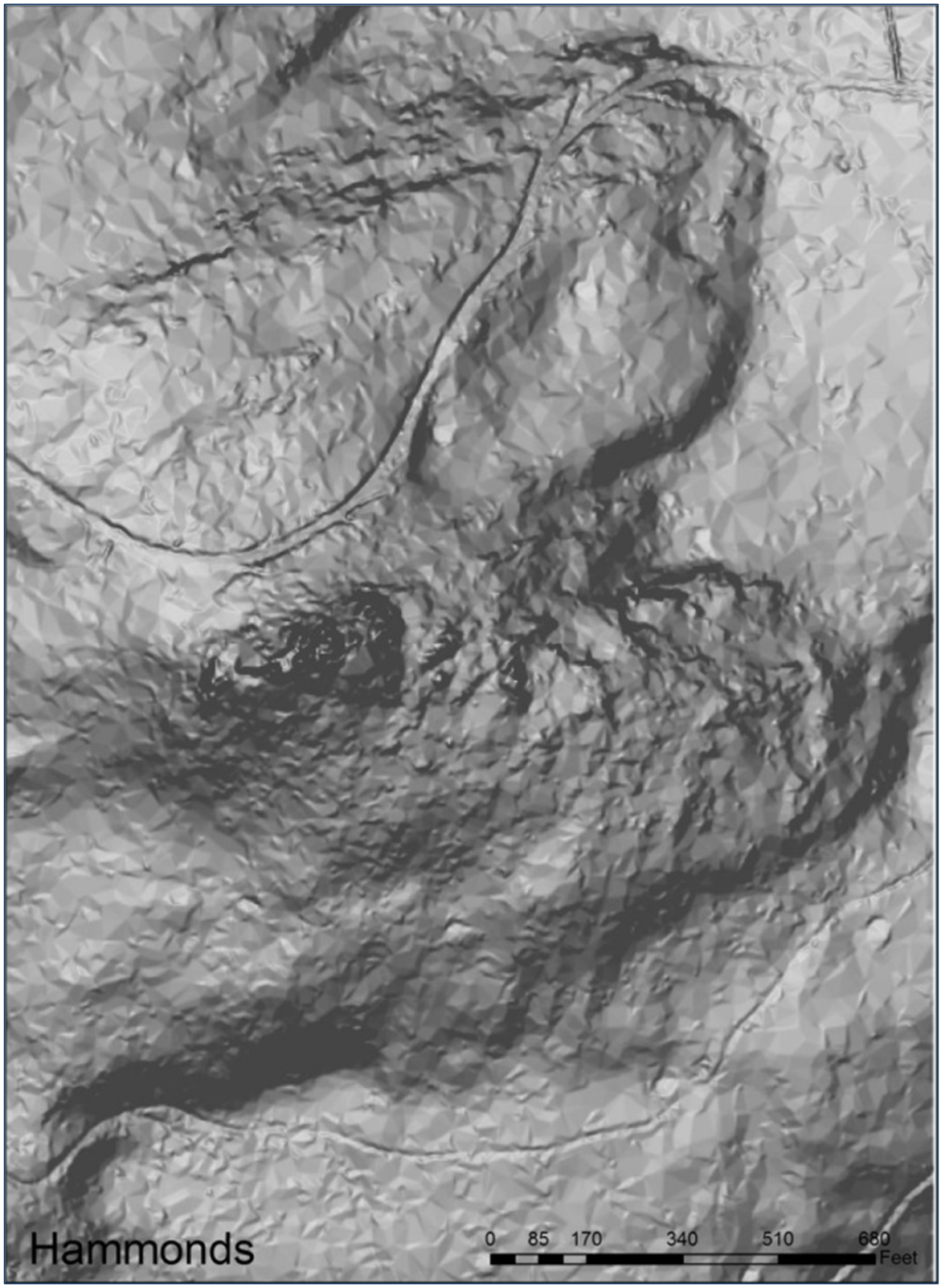


Figure 9. Enlarged LiDAR image of Hammonds Rocks (left center) and large lobes to the East.

References

Clark, G. M., 1991, South Mountain Geomorphology: *in* Sevon, W. D. and Potter, N., Jr., *eds.*, Geology in the South Mountain area, Pennsylvania: Guidebook for the 56th Annual Field Conference of Pennsylvania Geologists, p. 55-94.

Delano, H. L., Miller, N. G., Potter, N., Jr., 2002, Plant fossil evidence for late Pleistocene tundra conditions in south-central Pennsylvania: Geological Society of America, Northeastern Section, 37th Annual Meeting, Abstracts with Programs, v. 34, no. 1, p. 27.

Freedman, J., 1967, Geology of a Portion of the Mount Holly Springs Quadrangle, Adams and Cumberland Counties, Pennsylvania: Pennsylvania Geological Survey, 4th Series, Progress Report PR 169, 66 p.

Key, M. M., Jr., 1991, The Lower Cambrian Clastics of South Mountain, Pennsylvania: *in* Sevon, W. D. and Potter, N., Jr., *eds.*, Geology in the South Mountain area, Pennsylvania: Guidebook for the 56th Annual Field Conference of Pennsylvania Geologists, p. 21-28.

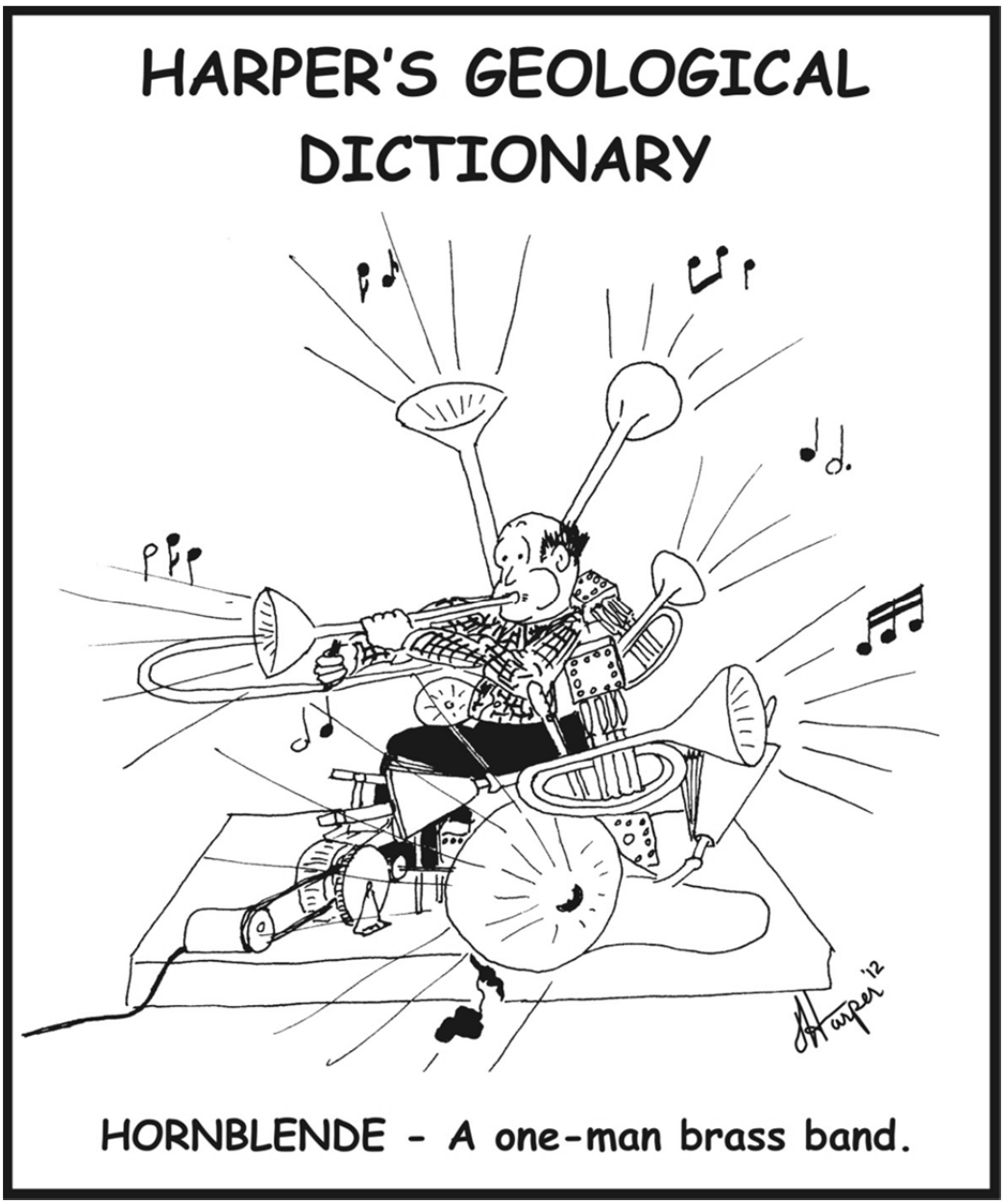
Lisle, R. J., 1985, Geological strain analysis, a manual for the Rf/Phi technique: New York, Pergamon Press, 11 p.

Pettijohn, F. J., 1962, Paleocurrents and paleogeography: Bulleting American Association of Petroleum Geologists, v. 46, no. 8, p. 1468-1493.

Potter, N., Jr., et al, 1991, Stop 8, Hammonds Rocks: *in* Sevon, W. D. and Potter, N., Jr., *eds.*, Geology in the South Mountain area, Pennsylvania: Guidebook for the 56th Annual Field Conference of Pennsylvania Geologists, p. 194-213.

Potter, N., Jr., et al, 1995, Mechanism of strain as indicated by deformed pebbles and sand grains, Whisky Spring, South Mountain, Cumberland Co., Pennsylvania: Dickinson College, Studies in Geology, No. 5 (Structural Geology class project), 19 p. plus tables.

Whitaker, J. C., 1955, Direction of current flow in some Lower Cambrian clastics in Maryland: Geological Society of America Bulletin, v. 66, no. 6, p. 763-766.


HARPER'S GEOLOGICAL DICTIONARY
HORNBLENDE - A one-man brass band.

Mileage Interval	Cumulative Mileage	**STOP = Stop Sign; = Traffic Light; "T" = T Intersection; TR = Township Route; "Y" = Y intersection**
0.0	18.5	Return on Ridge Road
2.7	21.2	STOP ***Turn right*** on PA 233, Centerville Road
3.4	24.6	STOP ***Turn left*** onto Pine Road
3.7	28.3	"T"; ***turn left*** on Mountain View Road; see photo. Note: use caution at this turn. Traffic arriving from right from the railroad underpass may suddenly appear. 
0.8	29.1	After ***sharp right turn*** (note farm buildings to left), quartzite cobbles mantle the local hill. These cobbles derive from South Mountain, seen to our left. How did they cross the large depression to get to this hill?
1.1	30.2	STOP **Turn left** on paved road (Furnace Hollow Road)
0.5	30.7	Continue past Foreman Hill Road
0.25	30.95	Steep side linear pit (sometimes water filled) to the left in forest was likely prospected as a bog iron ore source for nearby iron furnace. X-ray analysis of samples from this site show the material to be the mineral Goethite (personal communication, John Barnes, PA Geological Survey)
0.75	31.7	"Y" - Keep left on the unpaved road (still Furnace Hollow Road); do not follow paved road that curves 180 degrees to the right. **Note:** abandoned Big Pond Iron Furnace is immediately on left. Built in 1836, In 22 weeks in 1857 it produced 46.5 tons of iron from mines about 1 mile west (Lesley, 1859, p.??)
		**See "Pine Grove Furnace – A Brief Introduction & History" on page 5, for reference on iron-making from colonial times through the 1800's** **Big Pond Iron Furnace at mile 31.7**
0.05	31.75	Cross small stream with graffiti on cement bridge
0.05	31.8	**"Y" - *Turn right*** on gravel road (Hudleber Lane)
0.6	32.4	***Turn left*** onto paved Sand Bank Road
0.2	**32.6**	***ARRIVE* at plant entrance to Valley Quarries Mt. Cydonia III-STOP3**

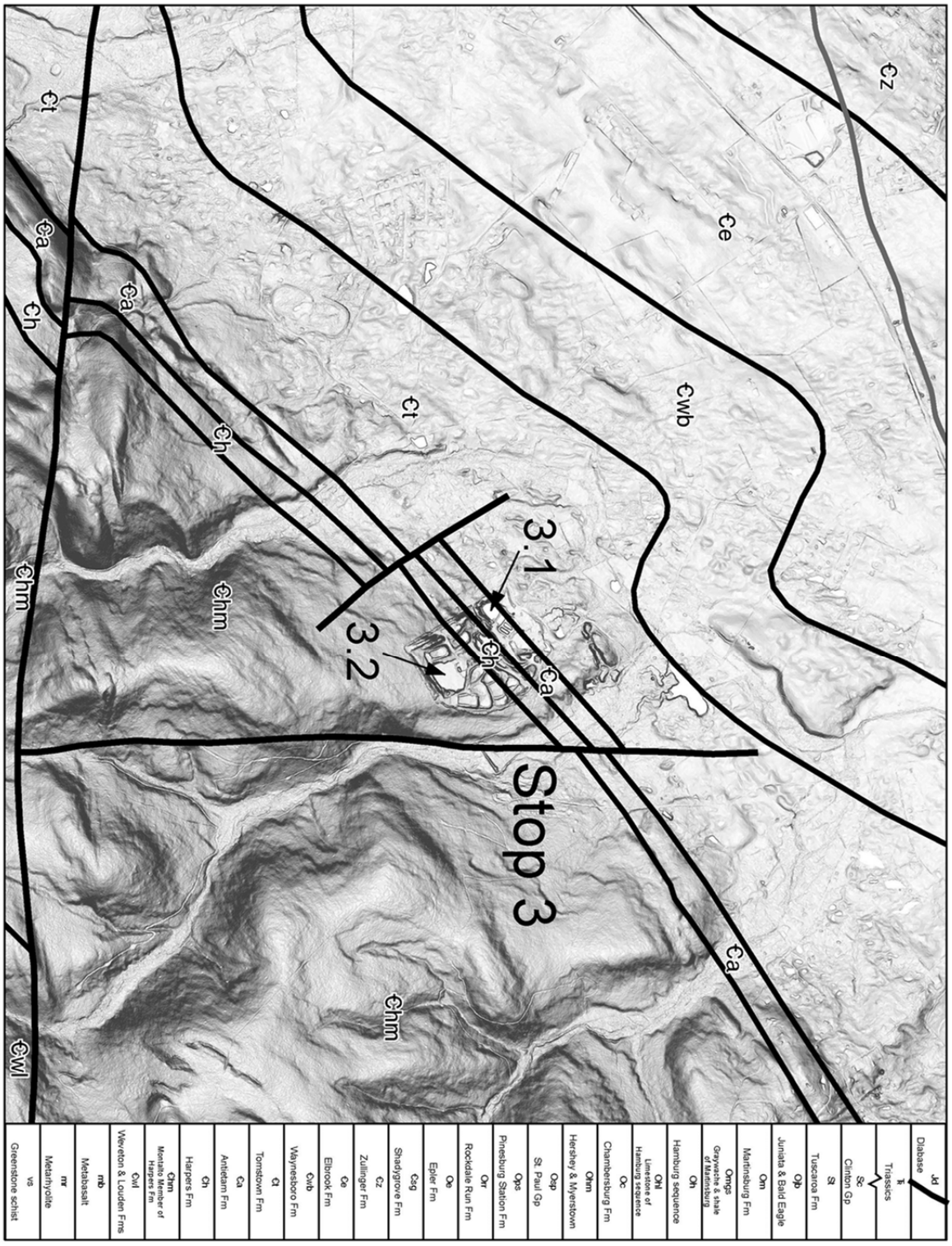


Figure 1. LiDAR image of Stop 3 – Mt. Cydonia Sand Plant III area, with geologic contacts overlain. Note processing plant at 3.1 and upper bench at 3.2

STOP #3. VALLEY QUARRIES, INC., MT. CYDONIA III QUARRY

(Entrance requires signed liability waiver)

Stop Leader: Marcus M. Key, Jr., Dickinson College

Entrance to Valley Quarries, Inc. Mt. Cydonia III Quarry

3.1 Processing Plant, Latitude = N40°03.238', Longitude = W77°24.926'

The quarry is located in the southwest corner of Cumberland County and is owned and operated by Valley Quarries. A small sand and clay mining interest existed at this location adjacent the Michaux State Forest for many years prior to its acquisition by Valley Quarries in 1999. Following this acquisition, the processing scheme was upgraded and a bench quarrying plan was implemented to allow for the blending of various areas of the deposit. The upper level of the pit is developed primarily in the Harpers Quartzite and the lower lifts transition into the Antietam. The quartzite throughout has been highly weathered to significant depths and as a result, large amounts of clay and silt must be processed out of the shot and quarried material in order to meet specifications. Since significant quantities of water are needed to scrub and wash the sand products, a fairly sophisticated treatment plant and fines recovery system has been employed to recycle all process water and allow for more efficient handling of the clay and silt by-products.

Valley Quarries sells stone, aggregate, blacktop, and ready-mix concrete in the Mid-Atlantic region. Mt. Cydonia Sand Plant III is their most recent commercial quarry in the Valley Quarries' family, and it produces four main aggregate products. 1) Washed concrete sand, also known as PennDOT Type A sand, which meets ASTM standard C33.

2) Washed masonry sand, which is a fine grade of sand also used as a bedding material in free stall dairy operations. 3) DEP sand that is certified for use in septic sand mounds. 4) A special "Ballfield Mix" of sand and clay with a rich red color. It is used in the infields of baseball and softball diamonds and also in the construction of horse racing tracks. This special mix is sold as far away as Staten Island, NY. As the main contributor to the price of aggregate is shipping costs, this product has a high value per unit weight than the more ubiquitous concrete and masonry sands which are only sold more locally.

3.2 Upper bench, Latitude = N40°03.016', Longitude = W77°24.688'

The upper bench is located on the south side of the Cumberland Valley on the northwest flank of the Blue Ridge Anticlinorium in the South Mountain Section of the Ridge and Valley Physiographic Province. The quarry is on the boundary between the Antietam and Harpers Formation *(Fig. 1–LiDAR)*, the youngest formations of the Chilhowee Group. The Antietam is conformably overlain by the dolostones of the Tomstown Formation and the Harpers is conformably underlain by the meta-conglomerates of the Weverton Formation (Stose, 1909; Freedman, 1967; Fauth, 1968; Root, 1968; Key, 1991; Smoot and Southworth, 2014).

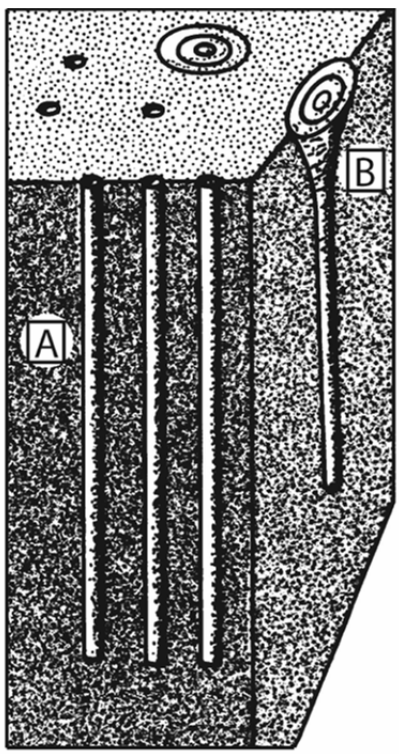


Figure 2. Schematic representation of (A) Skolithos and (B) Monocraterion trace fossils in plan and cross section view. Modified from Frey and Pemberton (1984, fig. 10).

The age of the Antietam and Harpers is constrained by a variety of paleontologic, radiometric, and stratigraphic evidence as 516.5-539 Ma in the Lower Cambrian (Smoot and Southworth, 2014). Following the Ediacaran to earliest Cambrian breakup of the supercontinent Rodinia and the opening of the Iapetus Ocean, they were deposited on the prograding shelf of the eastern-facing, passive, continental margin of Laurentia (Tull et al., 2010; Smoot and Southworth, 2014). Paleocurrent data indicate the primary terrestrial source was to the exposed Laurentian craton to the northwest (Dickinson et al., 1983; Tull et al., 2010). The Antietam Formation is a medium-to coarse-grained, white to grayish quartzite with *Skolithos* trace fossils present, whereas the Upper Harpers Member is a green to greenish-gray, quartzose phyllite, distinct from the underlying *Skolithos*-rich Montalto Quartzite Member (Fauth, 1968). *Skolithos* is a pipe-like cylindrical trace fossil *(Figure 2A)* (Key, 2014).

The eight numbered stops on this bench begin with 3.2.1 – 3.2.2 on the west side, 3.2.3 – 3.2.5 on the north side, and 3.2.6 – 3.2.8 on the south side *(Figure 3)*. You are welcome to collect hand samples. Feel free to examine the outcrop behind the berm; just make sure you have your hard hat on in case any loose pieces fall off the highwall. I will also pass around six vials containing *Skolithos linearis* tubes that have weathered out of their surrounding matrix. You are welcome to take one of these tubes as well.

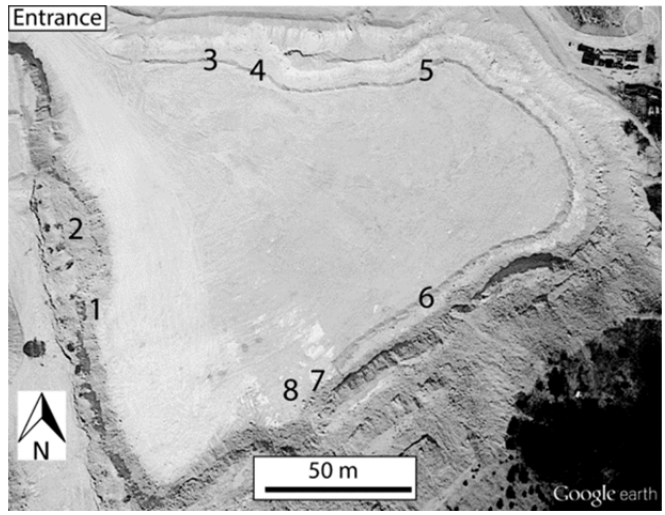


Figure 3. Google Earth image of Mt. Cydonia Sand Plant III's upper bench showing the 3.2.X stop numbers referenced in the text.

On a clear day, there is a good view across Cumberland Valley to Blue Mountain, 14 mi to the north through the entrance to this bench between stops 3.2.2 and 3.2.3. The finer-grained interbeds make it easy to see the bedding, especially at Stop 3.2.3. The *Skolithos* tubes are roughly perpendicular to bedding which also helps. Standing back from the highwall and looking around the bench, one can see that the beds strike parallel to the mountain and dip southeast toward the mountain indicating we're on the northwest limb of an overturned anticline. This is typical on the northwestern limb of the Blue Ridge anticlinorium, locally known as South Mountain, where the beds often dip to the southeast (Cloos, 1971).

The bedding exposed in this upper bench of the quarry strikes ~N51°E. But which way is stratigraphic up? Due to intense bioturbation by *Skolithos* and the overprinting of the Alleghanian subgreenschist metamorphism (Tull et al., 2010), it is hard to tell which way is up. The best evidence I found is concave up bedding at Stop 3.2.6 indicating stratigraphic up is to the northwest into the valley. That implies these beds are overturned, with a dip of ~61°SE. This makes sense as the more easily eroded dolostones of the overlying Tomstown Formation are to the northwest in the valley and the underlying more resistant quartzites and phyllites of the Harpers Formation are to the southeast in the ridge crest.

This southeast dip is in contrast to the online state geologic map (Figure 1) which is based on Berg's (1978) compilation which is based on Freedman's (1967) map to the northeast and Fauth's (1968) map to the southwest, both of which show the Antietam dipping to the northwest. The faults in Figure 1 are from Becher and Root (1981), and

if the location and throw of the faults are correct, but the dip backwards, then the Antietam should be displaced to the south as indicated in the quarry, not the north. I also question the mapped geology in Figure 1 due to the disconnect between the outcrop pattern of the overlying carbonates (esp. the Waynesboro Fm.) which shows a fold immediately north of the quarry but which is absent in the underlying Chilhowee siliciclastics.

I think the upper bench penetrates through the Antietam Formation into the underlying Harpers Formation. This is supported lithologically by the mapping of Fauth (1968) who reported a finer-grained upper member of the Harpers Formation immediately below the Antietam. He termed it the Upper Harpers Member and described it as a green to greenish-gray, fine-grained quartzose graywacke, distinct from the overlying *Skolithos*-rich Antietam and the underlying *Skolithos*-rich Harper's Montalto Quartzite Member (Fauth, 1968). I picked this lithologic break in the upper bench of the quarry by the presence-absence of *Skolithos*. Walking up section (i.e., to the north toward the valley) along the western highwall of this bench, you do not start to see *Skolithos* until Stop 3.2.1. Walking down section (i.e., to the south toward the mountain) along the opposite eastern highwall, you do not see *Skolithos* after Stop 3.2.5. Stops 3.2.1 and 3.2.5 are roughly along strike, and I interpret this as the contact between the younger, *Skolithos*-rich, cleaner, better sorted, whiter, metasandstone of the Antietam to the north and the older, *Skolithos*-poor, muddier, more poorly sorted, darker (browner/redder), metasandstone Harpers to the south.

For those of you with more paleontologic interests, at Stop 3.2.2 I have pulled out several samples of *Skolithos* tubes in the matrix and placed them on the berm in front of the highwall. Bedding planes are not well exposed on this bench; the best ones are at Stop 3.2.3. Do you see the *Skolithos* bottom end of the tubes (2-5 mm diameter) or the *Monocraterion* top end of the tubes (>5 mm diameter)? *Monocraterion* is a trumpet-like trace fossil *(Figure 2B)* (Key, 2014). The longest tube I found (i.e., 42 cm) was at Stop 3.2.4. Can you find one longer? At Stop 3.2.4 you are will find the Antietam quite weathered so the tubes become free from their matrix.

For those of you with more structural geology interests, I recommend you visit Stops 3.2.7 and 3.2.8. In contrast to the bedding, the jointing (which is best seen at Stop 3.2.7) runs roughly north-south and is basically vertical (strike: ~N155°E; dip: ~84°E). At stop 3.2.8 look at a different joint surface and see the undulating minor folds whose hinges are oriented ~N44°E and plunging ~9°NE. They parallel the general strike of the beds and the regional fold axis. Look for the quartz-filled extension veins with tapered ends that are exposed on the same surface.

The deformation of these beds is reflected by the normally circular transverse cross-sectional shape of the *Skolithos* burrows being distorted into an ellipse (Key,

2014). I measured the long (L) and short (W) axes of 13 *Skolithos* tubes and calculated the L/W (i.e., Rf strain) ratio as 1.9. This is less than the 2.2-2.8 values that Potter et al. (1991) measured on pebbles in the Weverton Formation at Hammonds Rocks, but more than the 1.6 that Key and Sims (1991) calculated in the Antietam Formation exposed in the Mt. Holly Pennsy Supply quarry. Gourley and Key (1996) measured the same ratio in the underlying Montalto Member of the Harpers Formation at Pole Steeple and reported a ratio of 1.5. See if you can find any deformed *Skolithos* tubes, especially at Stop 3.2.4.

References

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

Berg, T. M. 1978. Geologic map of the Walnut Bottom, PA Quadrangle. Pp. 597. In: T. M. Berg, and C. M. Dodge (eds.): Pennsylvania Geological Survey, 4th ser., Map 61, 1981.

Cloos, E. 1971. Microtectonics along the western edge of the Blue Ridge, Maryland and Virginia. Johns Hopkins Press, Baltimore, 234 p.

Dickinson, W. R., Beard, L. S., Brakenridge, G. R., Erjavec, J. J., Ferguson, R. C., Inman, K. F., Knepp, R. A., Lindberg, F. A., and Ryberg, P. T. 1983. Provenance of North American Phanerozoic sandstones in relation to tectonic setting. Geological Society of America Bulletin, 94 (2): 222-235.

Fauth, J. L. 1968. Geology of the Caledonia Park Quadrangle Area, South Mountain, Pennsylvania: Pennsylvania Geological Survey, 4th ser., Atlas 129a, 133 p.

Freedman, J. 1967. Geology of a portion of the Mount Holly Springs Quadrangle, Adams and Cumberland Counties, Pennsylvania. Pennsylvania Geological Survey, 4th ser., Progress Report 169, 66 p.

Freedman, J. 1968. Bender's Quarry- Mt. Holly Springs, Pennsylvania: in The Geology of Mineral Deposits in South Central Pennsylvania: Guidebook, 33rd Annual Field conference of Pennsylvania Geologists, p. 28-37.

Frey, R. W. and Pemberton, S. G. 1984. Trace fossils facies models. In: R.G. Walker (ed.), Facies Models. Geoscience Canada Reprints Series, pp. 189-207

Gourley, J. R., and M. M. Key, Jr. 1996. Analysis of the *Skolithos* ichnofacies from the Cambrian Montalto Quartzite Member of the Harpers Formation in south central Pennsylvania. Pp. 152. In: J. E. Repetski (ed.). North American Paleontological Convention Abstracts of Papers. Paleontological Society, Special Publication, No. 8.

Key, M. M., Jr. 1991. The Lower Cambrian Clastics of South Mountain, Pennsylvania. Pp. 21-27. In: W. D. Sevon and N. Potter, Jr. (eds.). Guidebook for the 56th Annual Field Conference of Pennsylvania Geologists. Field Conference of Pennsylvania Geologists. Harrisburg, PA.

Key, M. M., Jr. 2014. *Skolithos* in the Lower Cambrian Antietam Formation at South Mountain, Pennsylvania. Pp. 13-26. In: D. Hoskins and N. Potter, Jr. (eds.). Guidebook for the 79th Annual Field Conference of Pennsylvania Geologists. Field Conference of Pennsylvania Geologists. Harrisburg, PA.

Key, M. M., Jr. and S. J. Sims. 1991. Geology of the Pennsy Supply Quarry, Mt. Holly, Pennsylvania. Pp. 220-225. In: W. D. Sevon and N. Potter, Jr. (eds.). Guidebook for the 56th Annual Field Conference of Pennsylvania Geologists. Field Conference of Pennsylvania Geologists. Harrisburg, PA.

Potter, N., Jr., H. Hansen, R. Ackermann, G. Dockter, S. Lev, L. Pezzoli, and T. Troy. 1991. Stop 8. Hammonds Rocks. Pp. 194-213. In: W. D. Sevon and N. Potter, Jr. (eds.). Guidebook for the 56th Annual Field Conference of Pennsylvania Geologists. Field Conference of Pennsylvania Geologists. Harrisburg, PA.

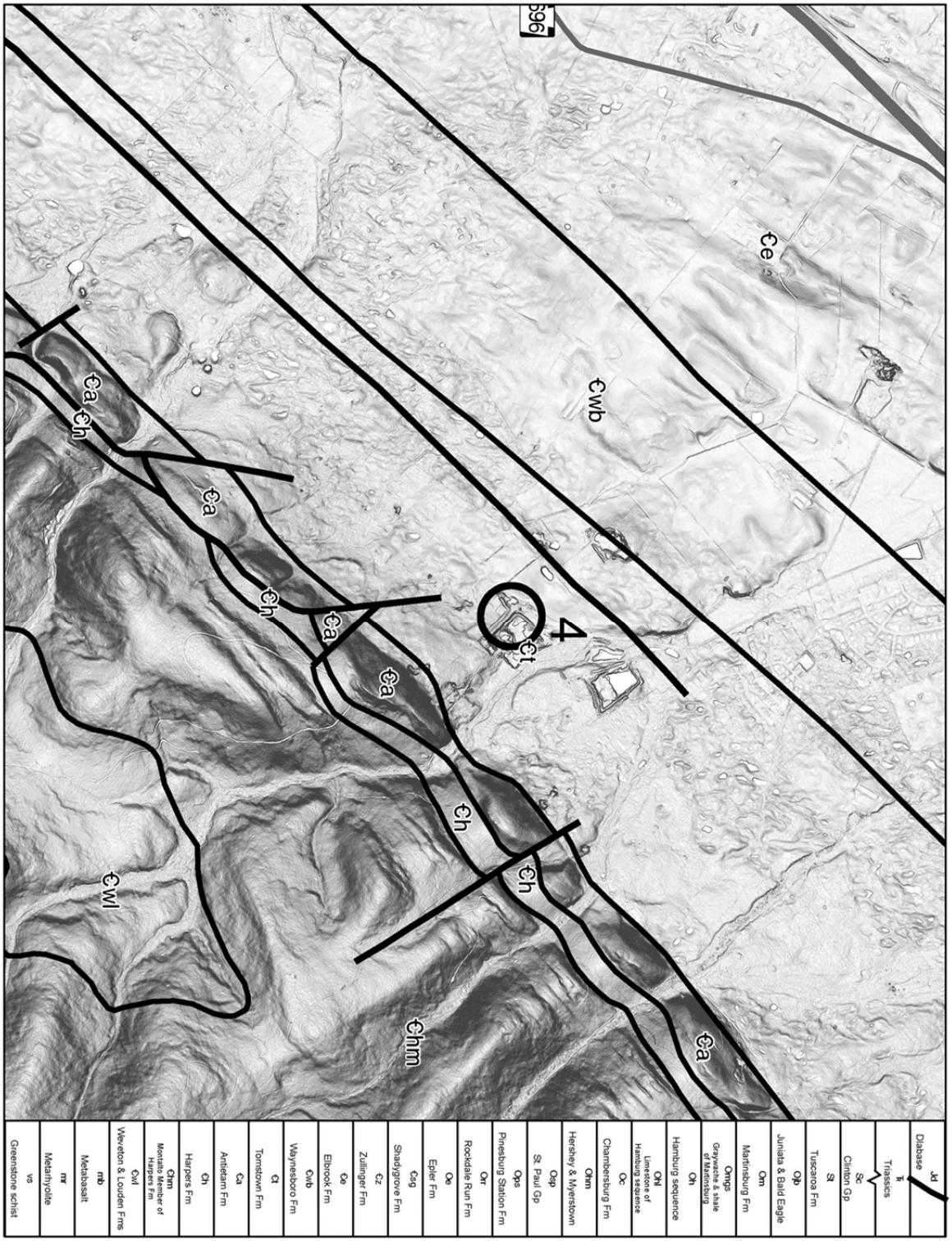
Root, S. I. 1968. Geology and mineral resources of Southeastern Franklin County, Pennsylvania Geological Survey, 4th Ser., Atlas 119cd, 118 p.

Smoot, J.P., and Southworth, S. 2014. Volcanic rift margin model for the rift-to-drift setting of the late Neoproterozoic-early Cambrian eastern margin of Laurentia: Chilhowee Group of the Appalachian Blue Ridge: Geological Society of America Bulletin, 126: 201-218.

Stose, G. W. 1909. Description of the Mercersburg-Chambersburg district, Pennsylvania, U. S. Geol. Survey Atlas, Folio 170, 19 p.

Tull, J. F., Allison, D. T., Whiting, S. E., and John, N. L. 2010. Southern Appalachian Laurentian margin initial drift-facies sequences: Implications for margin evolution, in Tollo, R. P., Bartholomew, M. J., Hibbard, J. P. , and Karabinos, P. M., eds., From Rodinia to Pangea: The Lithotectonic Record of the Appalachian Region: Geological Society of America Memoir 206, p. 935-956.

Mileage Interval	Cumulative Mileage	STOP = Stop Sign; = Traffic Light; "T" = T Intersection; TR = Township Route; "Y" = Y intersection
0.0	32.6	Drive southwest (left on exiting quarry) on Sand Bank Road
0.8	33.4	STOP **"T"** ***Turn left*** onto Strohm Road; **Note**: in opposite cut bank gravel mantles deeply buried carbonates
0.1	33.5	At the ***"Y"*** Take ***first right*** onto South Mt. Estates Road (TR 317). Numerous karst depressions are visible with the next couple of miles.
1.5	35.0	Continue on S. Mountain Estates Road to STOP at High Road, (TR 317) name changes to Airport Road.
1.4	36.4	Continue on Airport Road, passing Southampton Township offices at Neil Road, to 2nd entrance to Southampton Township Park (Beistle Park)
0.1	**36.5**	***Turn right*, continue to parking area near large pavilion** **DAY 1 LUNCH STOP, BEISTLE PARK, SOUTHAMPTON TOWNSHIP** **Exhibition of Pond Bank Core with Cretaceous Lignite** ***(refer to p.23)*** **optional visit to local caves** 
0.1	36.6	Return to Airport Road, **turn left**
1.1	37.7	Retrace route on Airport Road to "Y" intersection; ***turn right*** onto Witmer Road
0.2	37.9	STOP ***Turn right*** onto Gilbert Road
1.1	39.0	STOP At the 3-way intersection of Cleversburg, Gilbert and Walnut Dale Roads ***turn right*** onto Cleversburg Road; Cleversburg Road turns sharp left and then sharp right in Cleversburg village.
1.0	40.0	STOP Cross Baltimore Road, bearing left and then crossing to continue on McCulloch Road
1.8	41.8	Cross Means Hollow Road; enter Franklin County. As you approach Mainsville the road name changes to Mainsville Road
0.6	42.4	STOP ***Turn left*** on Lindsay Lot Road in Mainsville village
0.8	43.2	***Turn right*** and ***then immediate left*** onto un-named road at Quarry sign.
0.6	**43.8**	***ARRIVE* at Mainsville II quarry entrance – STOP 4**



LiDAR image of Stop 4 – Valley Quarries, Inc. Mainsville II area, with geologic contacts overlain

STOP #4. VALLEY QUARRIES, INC., MAINSVILLE II

(Entrance requires signed liability waiver)

Stop Leader Frank Pazzaglia, Lehigh University

View of Mainsville II Quarry from entrance

Late Cenozoic sedimentology, stratigraphy, and pedogenesis of the Furnace Creek fan

The stop at Valley Quarries, Mainsville (39°59'35.6" N, 77°30'32.1"W) is designed to provide a venue to discuss the geomorphology, stratigraphy, and landscape evolution of South Mountain and the Cumberland Valley. The pits exposed here at Mainsville have long been visited and discussed given the excellent exposures and gracious access by the Valley Quarries principals. Extraction at this site first opened in 1989. The sand and gravel deposits found in portions of the site have been mined extensively since that time with the run of pit material shipped off-site and processed at one of the company's sand plants near Fayetteville, PA. Originally, the finished products included sand and crushed aggregates of various sizes and grades used mainly in construction trades, highway building, landscaping, ready mixed concrete, and precast concrete products. More recently, due to changes within the marketplace and shifting of sand production to different locations, the use of the remaining sand and gravel reserves at this site has been curtailed. Mining activity here is now limited to the removal of a smaller amounts of special clay for use in the manufacture of a ball diamond infield mix. Reclamation of

certain pit areas is also ongoing, as well as a portion of the site being used as a testing and proving ground for Volvo Construction Machinery.

Notable previous research at the site includes general geomorphology and stratigraphic descriptions (Sevon, 1991; Potter and Sevon, 2011; Sevon, 2013), detailed mapping, sedimentologic, and pedologic descriptions (Grote, 2006; Grote and Kite, 2006), and analysis of clastic dikes and karst-collapse features (Sevon, 1994). In general, these studies are part of a broader effort by geomorphologists in the mid-Atlantic region that has investigated similar geomorphology and late Cenozoic stratigraphy on the western flank of the Blue Ridge (Wittecar, 1985; Wittecar and Duffy, 2000; Eaton et al., 2003). Long recognized as a source of iron and manganese ore (Hack, 1965), limited, but intriguing geochronology establishes a framework for the great antiquity of some of these deposits and residuum in the modern landscape (Pierce, 1965; Bikerman et al., 1999).

The goal of the present study builds upon the above scholarship with the expressed goal of trying to understand the genesis of these deposits in the context of environmental change and long-term landscape evolution of the mid-Atlantic region. Specifically, the Valley Quarries exposures provide a window into several, deeply-weathered paleosols that speak to an unsteadiness in deposition, landscape stability, and pedogenesis. We are interested in better understanding the temporal and genetic context of that unsteadiness and how it influences our thinking of the late Cenozoic, mostly erosion history of the Appalachians.

Geomorphology of the western flank of South Mountain

The piedmont that forms the western flank of South Mountain has long been recognized to be a zone of deep weathering of the carbonate bedrock underlying the Cumberland Valley juxtaposed against the relatively resistant Antietam Fm ridge that underlies the western flank of South Mountain (Pierce, 1965; Becher and Root, 1981). Dissolution of the carbonates results in local subsidence and the production of accommodation space to trap sediment shed from South Mountain. As a result, and in contrast to most of the rest of the mid-Atlantic region, a rich record of erosion is preserved here in the form of large, thick, alluvial, colluvial, and debris-flow fans that otherwise are thin or absent in the rest of the erosion Appalachian landscape. A similar rich stratigraphic record of late Cenozoic deposits and erosional unroofing of the post-orogenic Appalachians is not encountered until one travels to the Coastal Plain.

Detailed maps and stratigraphy of the South Mountain piedmont can be obtained from several published and unpublished sources including Grote (2006), Grote and Kite (2006) and Merritts et al. (this guidebook). Here, our goal is to provide a basic, portable, geomorphic and lithostratigraphic framework that is mappable at a scale of 1:24,000. The large alluvial-colluvial fan that spills westward from South Mountain at this locality has been built by Furnace Run and Shirley Run that meet in the town of Mainsville so we refer to the fan as the Furnace Run fan. There are three main, and several minor geomorphic surfaces associated with this fan complex (Fig. 1). The main surfaces are denoted as Qf1, Qf2, and Qf3 and all three are underlain by distinct lithostratigraphic and pedostratigraphic units. Minor surfaces or treads cut into these units are denoted with the subscripts a, b, etc, such as Qf2a. The cross-section clearly shows the inset nature of the three main surfaces and their underlying deposits (Fig. 1b). Distal equivalents to these piedmont fans, not shown in Fig. 1, are known to be preserved further west in the Cumberland Valley. Active sinkholes and disrupted drainages are clear evidence of ongoing dissolution and subsidence beneath the piedmont fan cover.

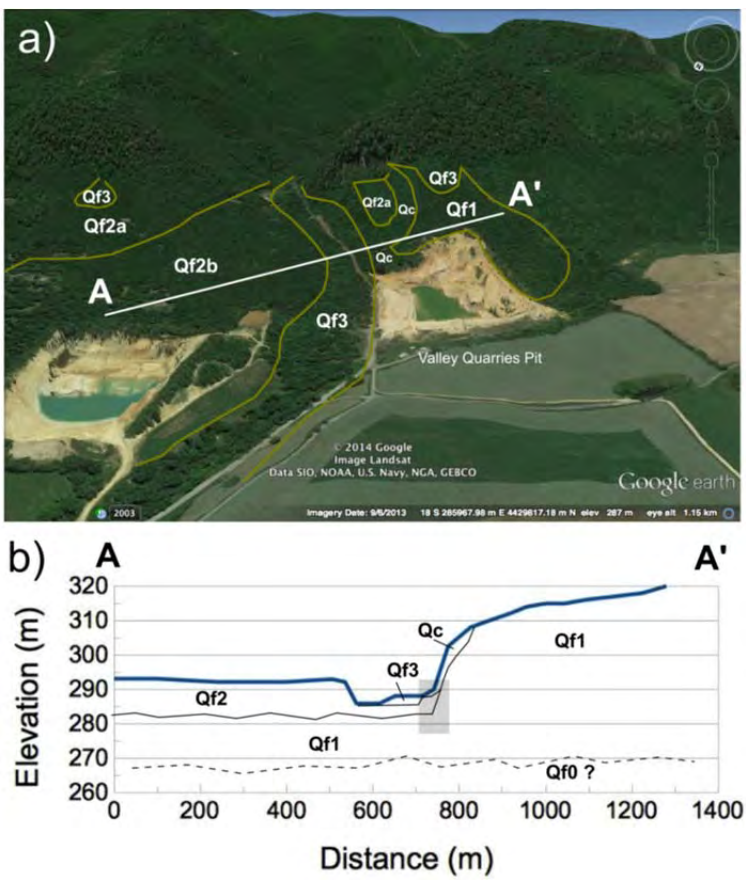


Figure 1. (a) Oblique view to the SSE of the western flank of South Mountain, including piedmont alluvial fans, showing approximate outlines of major geomorphic surfaces. These surfaces are interpreted to be part of a large fluvial-colluvial fan complex and are underlain by the lithostratigraphic units identified in (b) the cross section and Fig 2. The shaded box in (b) indicates the location of the stratigraphic column in Fig. 2. Qf1, Qf2, and Qf3 are described in the text, Qc = colluvium.

Base image from Google Earth

Fan lithostratigraphy

Fan surfaces Qf3, Qf2, and Qf1 are underlain by litho- and pedostratigraphically distinct deposits that are mappable at a scale of 1:24,000 (Fig. 1b and Fig. 2). In general, these three deposits crudely correlate to the LQa, LPc-a, and M-EP-a-c deposits of Grote and Kite (2006), respectively. These three units bury a thick, undivided subsurface deposit with no corresponding geomorphic surface, here denoted as Qf0 and in Grote and Kite (2006) as subsurface sand and gravel. The Qf0 deposit hosts the Pond Bank lignite (see Pazzaglia, this guidebook) and unconformably overlies tens of meters of residuum and saprolite formed from dissolution of the carbonate bedrock (Tomstown and Waynesboro fms).

Qf1 is characterized by red, orange, white, and yellow gravel, sand, silt, and clay. Gravel clasts are mostly saprolitized and there is significant clay coating sand grains and as matrix material (Fig. 2). There are several buried soils in the Qf1 unit, all of which show evidence of intense weathering. Depositional facies are dominated by poorly-sorted hyperconcentrated alluvial and debris flows with lesser examples of alluvial and colluvial facies. Bedding is indistinct and commonly distorted presumably by karst subsidence and clastic dike injection (Sevon, 1994). At 10s of meters thick, Qf1 is the thickest deposit underlying the Furnace Creek fan.

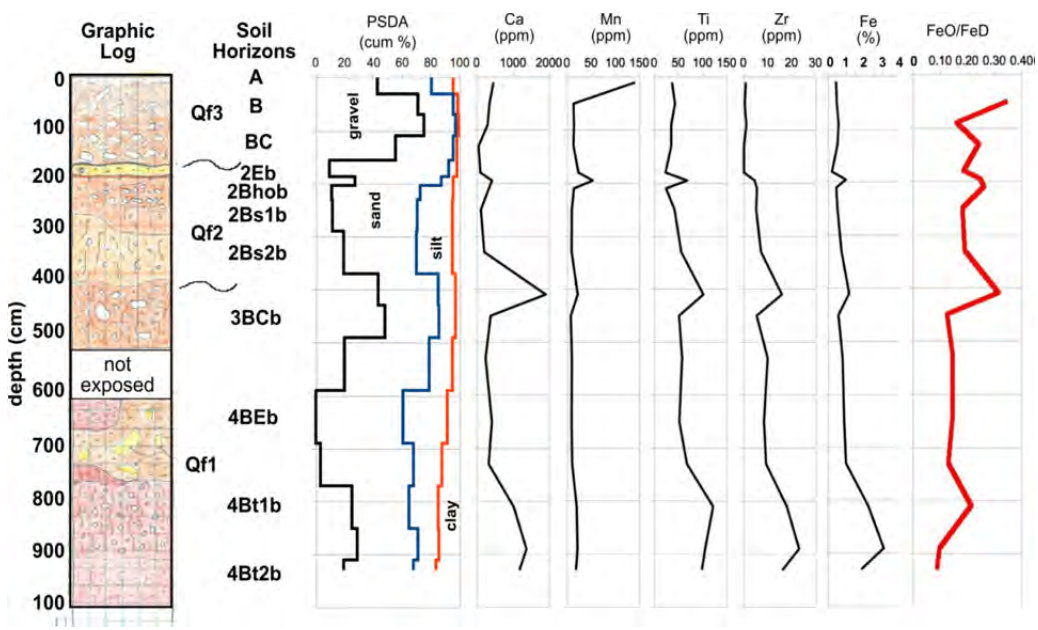


Figure 2. Summary plot of lithostratigraphic, soil stratigraphic, and soil weathering data for the north wall of the Valley Quarries pit. Particle size distribution analysis (PSDA) follows standard NRCS pipette procedures. All chemical data concentrations are reported with respect to the iron-dithionate leach fraction. Ca and Mn represent mobile elements whereas Ti and Zr represent elements traditionally held to be immobile and conserved in the weathering profile. The amorphous iron (FeO) to crystalline iron (FeD) ratio is expanded upon in Fig. 3

Qf2 is 1-10 m thick, white, yellow, and salmon-colored sand and gravel, also deeply weathered, but less so than Qf1. Qf2 contains more silt and less clay than Qf1 (Fig. 2), has more organized bedding, and is comparatively better sorted. The Qf2 facies are thought to be a mix of alluvial and hyperconcentrated flows with lesser amounts of debris flows and colluvium. One or more paleosols are also present in Qf2, one of which preserves a buried spodosol, characteristic of the modern soil forming environment altering similar parent material. Qf2 is less thick overall than Qf1 and underlies the fan lobe north of Furnace Creek. Qf2 is everywhere inset into Qf1.

Qf3 occurs in two landscape positions on the Furnace Creek fan (Fig. 1). Along Furnace Creek and Shirley Run, Qf3 is a brown, moderately well-sorted and stratified sandy gravel alluvial deposit that is inset into both Qf2 and Qf1 where it is stratigraphically younger, but topographically lower than the other fan units. The depositional facies is interpreted to be alluvial and hyperconcentrated alluvial stream deposits. Qf3 occupies a second landscape position as small alluvial-colluvial-debris flow fans sourced in the Antietam ridge, and deposited atop Qf1 or Qf2 at the heads of these older units. In this landscape position, Qf3 is both younger and topographically higher than Qf2 and Qf1. Qf3 is only gently modified by weathering and pedogensis.

All depositional facies, the stark unconformities and soils bounding the three main lithostratigraphic packages, and overall geomorphology of the Furnace Creek fan are consistent with unsteady production of sediment in South Mountain watersheds and unsteady transport of that sediment to the piedmont over 10^3-10^5 yr time scales. Periglacial processes and repeated glacial-interglacial cycles have undoubtedly played a role in this unsteadiness (Sevon, 1991; Potter and Sevon, 2011; Sevon, 2013; Grote, 2006; Grote and Kite, 2006), but the precise links remain elusive. Investigation of the modern landscape using LiDAR and synoptic classification of the myriad of talus, colluvial, and related cold-climate deposits (Merritts et al., this guidebook) provide an excellent analogue model for the processes responsible for creating the lithostratigraphy described here.

Pedogenesis, weathering, and age model

The soils formed in the three main lithostratigraphic units form a basis for understanding when they were deposited and the prevailing environmental conditions that has driven their subsequent weathering (Figs. 2 and 3). Significant changes in the concentrations of traditionally-held mobile and immobile elements occur at litho- and pedostratigraphic boundaries (Fig. 2). These changes are probably the result of accumulations and depletions that occurred during pedogenesis and subsequently by groundwater and diagenesis.

We focus on the iron chemistry as a crude measure of deposit age by correlation to what is (poorly) known about soil ages in the mid-Atlantic region. In soil profiles, iron is known to occur as amorphous non-crystalline iron-oxy-hydroxides as well as crystalline minerals such as hematite (reviewed in McFadden and Weldon, 1985). As iron in soil parent materials weather, the amorphous phases are produced and early in the development of a soil, they dominate the iron chemistry. With the passage of time, these amorphous iron phases transform to crystalline hematite, goethite, jarosite, etc, that accumulate and ultimately dominate the iron chemistry of old soils. As a result, the amorphous to crystalline phase ratio initially starts out relatively high (0.3-0.5) but then decreases with time towards zero. The amorphous iron phase is extracted from a soil sample using a oxalate leach procedure and is called the oxalate iron fraction, FeO. The crystalline phase is extracted using a citric dithionite leach and is called the dithionite iron fraction, FeD. Insofar that we know the numeric ages of some soils and buried soils in the Appalachian landscape, the FeO/FeD ratio can be used as a crude tool in determining soil age and provides a means for correlation (Ciolkosz et al., 1993).

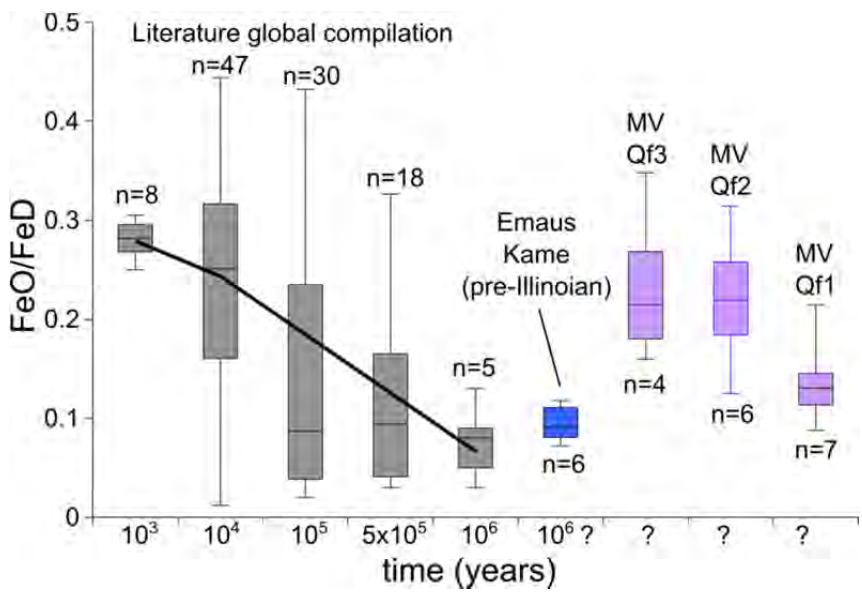


Figure 3. Plot of soil oxylate-extractable iron to dithionite-extractable iron ratio for soils assembled from the literature in comparison to the three main litho-pedostratigraphic units exposed in the Valley Quarries pit and the pre-Illinoian kame delta exposed at Emaus, PA. References used in the compilation of the global data are Ciolkosz et al., 1983; McFadden and Weldon, 1987; Layzell et al., 2012; Eppes et al., 2008.

The FeO/FeD data from Qf1, Qf2, and Qf3 are plotted with respect to an incomplete but representative global compilation of FeO/FeD data that is heavily weighted by Pennsylvania soil and paleosol data (Ciolkosz et al., 1993; Fig. 3). Also plotted are the FeO/FeD ratio from a soil developed in a pre-Illinoian kame delta exposed in Emaus, PA (Braun, 1996). The Emaus kame soil is an important one to use because if intact, it has

been in the landscape for > 788 ka (Braun, 1996), making it significantly older than most of the LGM and Illinoian soils described on well-preserved tills (Ciolkosz et al., 1993) but also significantly younger than the Tertiary Coastal Plain deposits that are known to be pre-glacial based on biostratigraphy (Pazzaglia et al., 1997). We note that the FeO/FeD ratios of Qf1, Qf2, and Qf3 are at least consistent with their relative stratigraphic age. The ratios suggest that Qf2 and Qf3 are Holocene to late and perhaps middle Pleistocene age deposits. In contrast, Qf1 is a middle, or even early Pleistocene deposit. Corresponding FeO/FeD ratios for Tertiary Coastal Plain gravels have not been compiled for this study, but remain a goal for our ongoing research.

REFERENCES

Becher, A. E. and Root, S. I., 1981, Groundwater and geology of the Cumberland Valley, Cumberland County, Pennsylvania: Pennsylvania Geologic Survey, 4th ser., Water Resource Report 50, 95 p. (online at www.dcnr.state.pa/topogeo/pub/water/w050.aspx)

Bikerman, M., Myers, T., Prout, A.A., and Smith, R.C, 1999. Testing the feasibility of KAr Dating of Pennsylvania cryptomelanes [potassium manganese oxides]: Journal of the Pennsylvania Academy of Science, v. 72, pp. 109-114.

Braun, D., 1996, Surficial Geology of the Allentown East 7.5' quadrangle, Lehigh, Northampton, and Bucks Counties, Pennsylvania: Pennsylvania Geological Survey Open-File Report 96-43, 15 p.

Ciolkosz, E. J., Waltman, W. J., and Thurman, N. C., 1993, Iron and Aluminum in Pennsylvania soils: Penn State University Agronomy Series 127, 33 p.

Eaton, L. S., Morgan, B. A., Kochel, R. C., and Howard, A. D., 2003. Quaternary deposits and landscape evolution of the central Blue Ridge of Virginia: Geomorphology, v. 56, p. 139-154.

Eppes, M. C., Bierma, R., Vinson, D., and Pazzaglia, F., 2008, A soil chronosequence study of the Reno valley, Italy: Insights into the relative role of climate verses anthropogenic forcing on hillslope processes during the mid-Holocene: Geoderma, 147, 97-107.

Grote, T. and Kite, J. S., 2006, Surficial geology of the northwestern footslope of South Mountain, south-central Pennsylvania: USGS EDMAP program Open File Report 05HQAG0045, 34 p.

Grote, T. D., 2006 Late Cenozoic Stratigraphy and Landscape Dynamics in the Unglaciated Central Appalachians - a Case Study from the Northern Blue Ridge, South-Central Pennsylvania, USA (Ph.D. Dissertation): Morgantown, West Virginia University, 117 p., URL: https://eidr.wvu.edu/eidr/documentdata.eIDR?documentid=4954

Hack, J.T., 1965, Geomorphology of the Shenandoah Valley, Virginia and West Virginia and the origin of the residual ore deposits: U.S. Geological Survey Professional Paper 484, 84 p.

Layzell, A. L., Eppes, M. C., and Lewis, R. Q., 2012, A soil chronosequence study on terraces of the Catawba River near Charlotte, NC: Insights into the long-term evolution of a major Atlantic Piedmont drainage basin: Southeastern Geology, 49, 13-24.

McFadden, L. D. and Weldon, R. J., 1985, Rates and processes of soil development on Quaternary terraces in Cajon Pass, California: Geological Society of America Bulletin, 98, 280-293.

Pazzaglia, F. J., Robinson, R., and Traverse, A., 1997, Palynology of the Bryn Mawr Formation (Miocene): Insights on the age and genesis of middle Atlantic margin fluvial deposits: Sedimentary Geology, v. 108, p. 19-44.

Pierce, K. L., 1965, Geomorphic significance of a Cretaceous deposit in the Great Valley of southern Pennsylvania: US Geological Survey Professional Paper 525C, p. C152-C156.

Potter, N., Jr. and Sevon, W. D., 2011, Geology and geomorphology of the South Mountain area, Cumberland and Franklin Counties, Pennsylvania: Harrisburg Area Geological Society, 20th Field Trip, 64 p. (Stop 6 is Mainsville.)

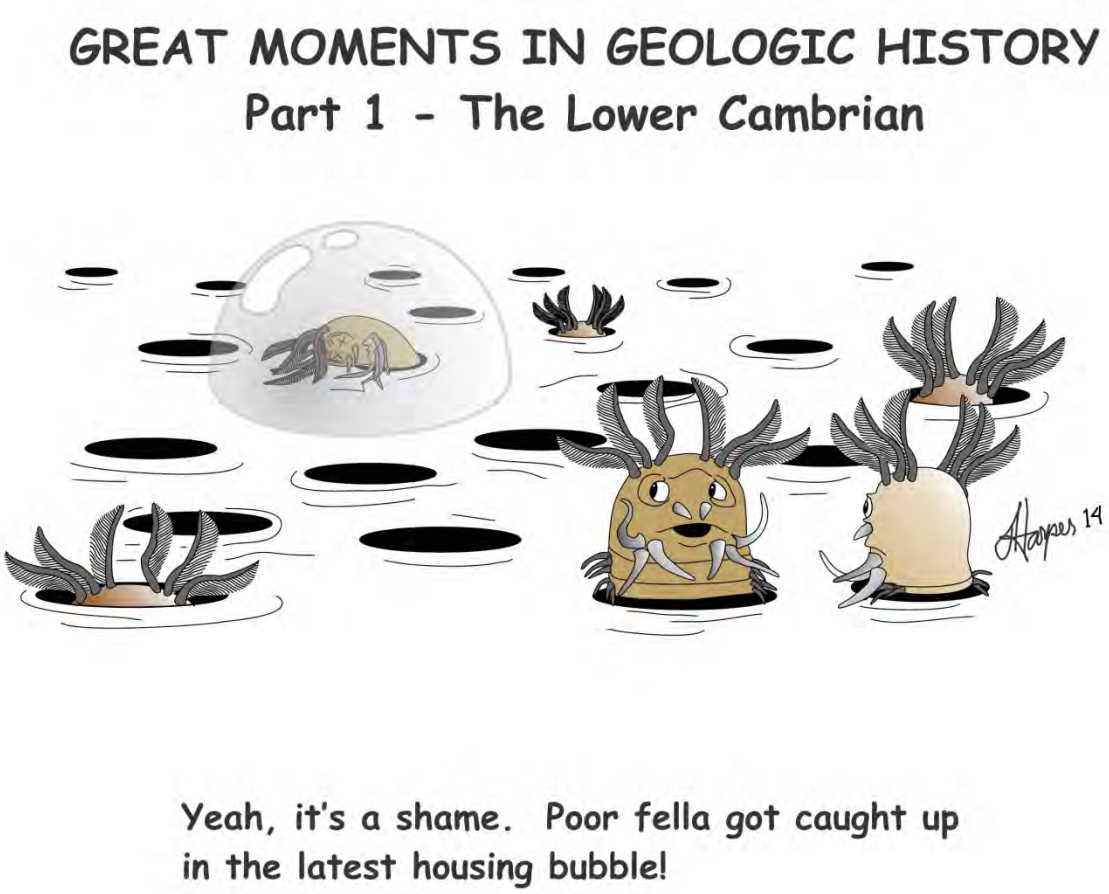
Sevon, W. D., 1991, Stop 6. Mainsville quarry, Valley Quarries, Inc., in Sevon, W. D. and Potter, N. Jr., eds., Geology in the South Mountain area, Pennsylvania: Field Conference of Pennsylvania Geologists, Annual Field Trip, 56th, Guidebook, p. 176-188.

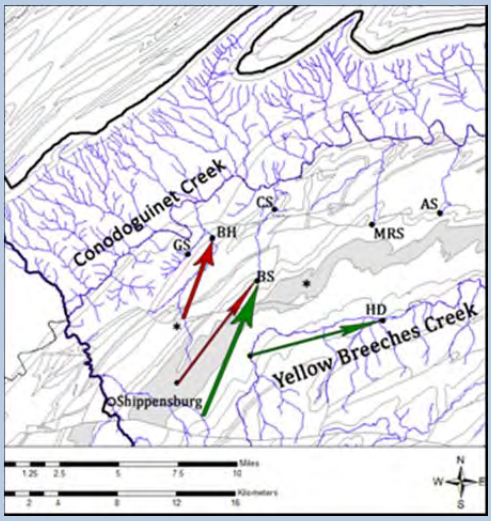
Sevon, W. D., 1994, Solution below, injection within, and subsidence throughout alluvial-fan deposits, South Mountain, Pennsylvania: Geological Society of America, Abstracts with Programs, v. 26, no. 3, p. 72.

Sevon, W. D., Day 2, Stop 3, Mainsville (p. 90-97), *in* Potter, N., Jr., Merritts, D., Walter, R., Clark, G. M., Pazzaglia, F., Price, J., and Sevon, W. D., 2013, Geomorphology of the South Mountain Area, Cumberland and Franklin Counties, Pennsylvania: Southeast Friends of the Pleistocene, 2013 Field Trip, Guidebook, 106 p.

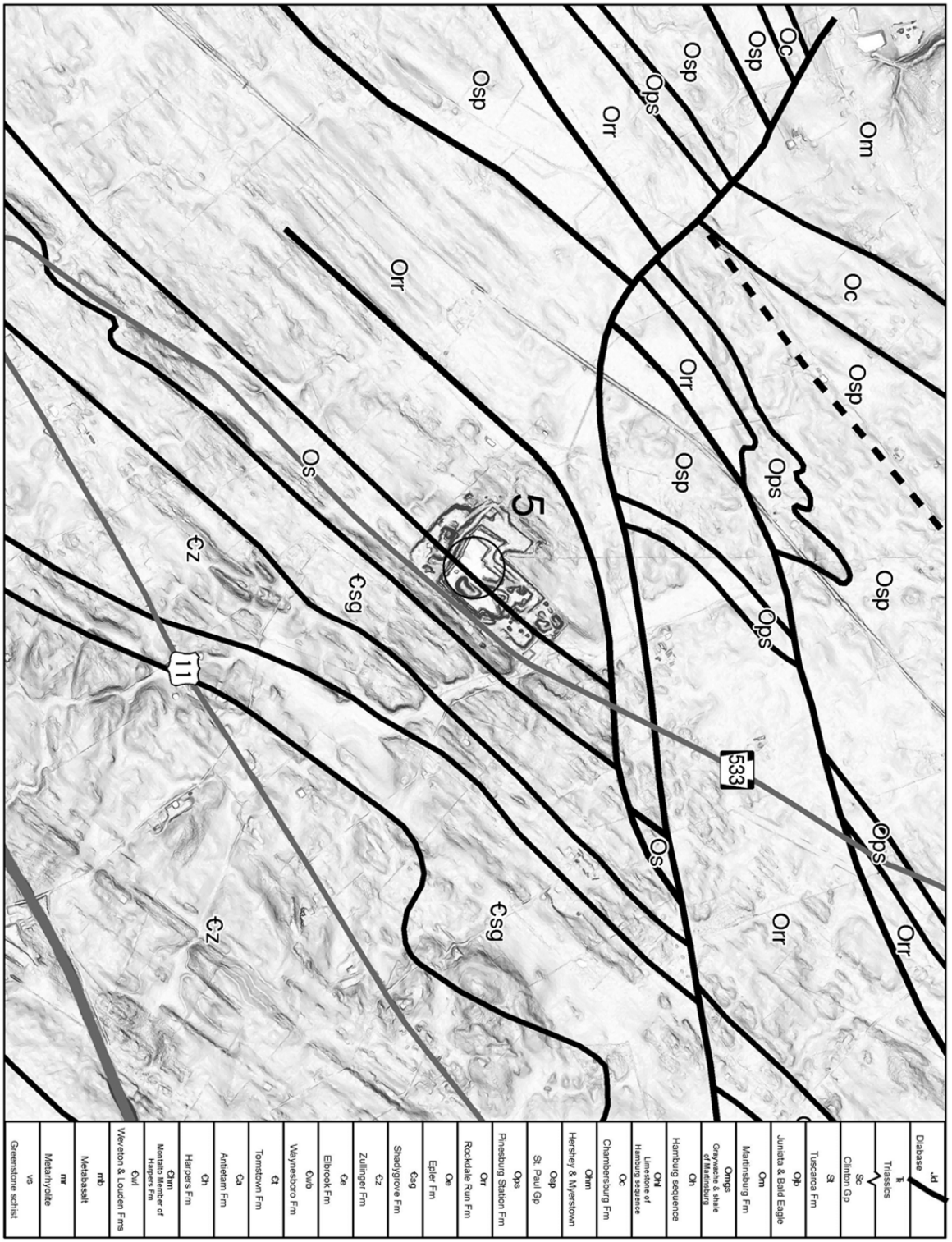
Whittecar, G.R. and Duffy, D.F., 2000, Geomorphology and stratigraphy of Late Cenozoic alluvial fans, western Virginia, U.S.A.: Southeastern Geology, v. 39, p. 259-280.

Whittecar, G.R., 1985. Stratigraphy and soil development in upland alluvium and colluvium, North-central Virginia Piedmont: Southeastern Geology, v. 26, p. 117-129.


GREAT MOMENTS IN GEOLOGIC HISTORY
Part 1 - The Lower Cambrian
Yeah, it's a shame. Poor fella got caught up in the latest housing bubble!

Mileage Interval	Cumulative Mileage	STOP = Stop Sign;  = Traffic Light; "T" = T Intersection; TR = Township Route; "Y" = Y intersection
0.0	43.8	Return northward toward Lindsay Lot Road; ***turn left*** on Lindsay Lot Rd
0.8	44.6	STOP ***Turn right*** on Mainsville Road
0.6	45.2	Cross Means Hollow Road; re-enter Cumberland County, road name changes to McCulloch Road
1.8	47.0	STOP ***Cross*** Baltimore Road; continue on Cleversburg Road
1.0	48.0	At 3-way intersection of Cleversburg, Gilbert and Walnut Dale Roads, ***turn left*** onto Gilbert Road
0.9	48.9	**Turn left** onto Witmer Road
0.3	49.2	STOP ***Turn left*** onto Airport Road
1.0	50.2	At 4-way intersection of Airport, Hershey and Neil Roads **turn right** onto Hershey Road; Southampton Township offices are to the right.
0.9	51.1	STOP ***Turn left*** onto Walnut Bottom Road; cross over I-81
0.2	51.3	***Turn right*** onto Cramer Road (*immediately past the I-81 off-ramp*)
0.5	**51.8**	**Groundwater flowpaths in western Cumberland County, PA traced with fluorescent dyes since 2005.** *(Figure from Pennsylvania Geology, v.42 no. 3, Fall 2012)*  **Cramer Road Dye Trace Site**: (40°3'58.1"N, 77°28'22.9"W) The first modern dye trace in the Cumberland Valley occurred in 2005 when a fluorescent dye was injected at this site (butt end of green arrow shaft) into a failed storm water detention basin during a summer thunderstorm (Hurd et al. 2010). Review of regional water table maps suggest that groundwater in this region flows to the north toward the regional drain, the Conodoguinet Creek. Charcoal receptors were placed at eight springs to the north and east of the injection site that were considered

		potential emergence points; two of the sites were at Big Spring ("East" and "West" springs). Collected over a two-week period at all eight sites water samples were analyzed on a spectrofluorophotometer. Evaluation of collected spring water samples revealed a spike in dye concentration 3.5 days after injection at Big Spring, 8.9 km to the north and east. A groundwater flow velocity of 2.5 km/day was based upon the linear distance and 3.5-day travel time. A second dye released into the upper Yellow Breeches Creek at Walnut Bottom was detected at Huntsdale Hatchery springs. This dye trace provided the first direct evidence of how the strike influenced groundwater flow in the Cumberland Valley karst aquifer, and in turn the anisotropic nature of flow here. Subsequent dye traces from other locations have followed much the same path.
0.9	52.7	Continue on Cramer Road to intersection with US Route 11. STOP ***Turn right*** on US 11
0.4	**53.1**	Just past the intersection of US 11 with Goodheart Road (to the left) is a lengthy outcrop of the Cambrian Zullinger Formation (Becher & Root, 1981). Here, and in additional outcrops along both sides of US 11 for the next mile, can be seen the formation's characteristic dark-gray limestone lithology with laminae and crenulated siliceous seams as well as the region's prominent strike parallel and perpendicular joint sets. Calcite veins fill many joints as well as occur in layer parallel fractures.  **Cambrian Zullinger Formation exposed at mileage 53.7**
0.8	53.9	***Turn left*** onto Foltz Road; = TR 4003
0.9	54.8	STOP ***Turn right*** onto PA Route 533
0.6	**55.4**	***ARRIVE*** **at plant entrance to Valley Quarries on left – STOP 5**



LiDAR image of Stop 5 – Valley Quarries, Inc. Shippensburg area, with geologic contacts overlain

STOP 5 – VALLEY QUARRIES, SHIPPENSBURG

(Entrance requires signed liability waiver)

Stop Leaders – Economics – Valley Quarries staff
Geology – Donald Hoskins, PA Topo & Geologic Survey, Retired
Noel Potter, Dickinson College, Retired

Entrance to Valley Quarries Shippensburg

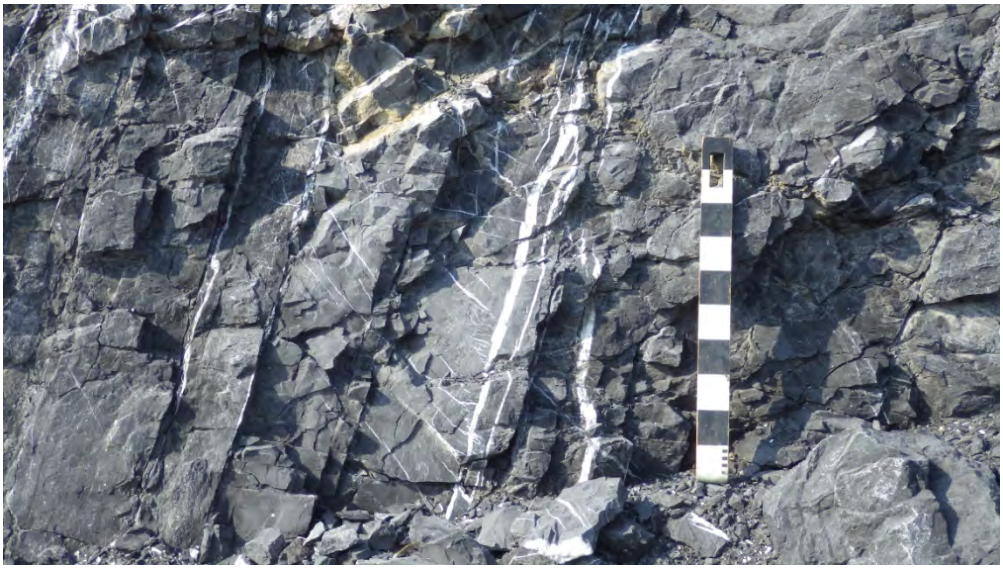
Quarried here (40°5'53.5"N, 77°28'24.6"W) since 1936 the quarried rock includes the Ordovician Stonehenge and Rockdale Run Formations of ~450 million years. "Physical characteristics vary minimally between the formations as does the carbonate geochemistry which typically falls between 80 and 90%. The full range of typical crushed aggregate sizes and grades are produced here from pulverized limestone fines all the way to gabion stone and Rip-Rap. A large portion of the aggregate production is consumed internally to supply the company's concrete and hot mix asphalt (Blacktop) operations which in turn sell to individuals, private contractors, and state and municipal agencies as well as in-house construction and paving crews who rely on these value added products to complete their highway and paving projects throughout the region. Many miles of pavement on the nearby Interstate Route 81 and the PA Turnpike have been constructed with stone from the Shippensburg quarry." *(Randall Van Scyoc, Vice President, Valley Quarries, Inc.)*

View to west of contact (left edge of buff zone) of the Stonehenge and Rockdale Run Formations in the Valley Quarries, Shippensburg.

The Stonehenge Formation (to the left of the light colored band in the photo above) is "light to medium gray, micrograined to micritic limestone containing zones and beds that are detrital to skeletal–detrital" (Root and Becher, 1981). Unfortunately, access to this part of the stratigraphic section is difficult without wading through water and very fine-grained mud that accumulates rapidly and remains stuck on footwear. The Stonehenge is not actively mined here because quarrying is focused to the north in the Rockdale Run Formation.

View of east wall showing repetitive light colored dolomitic zones characteristic of the Rockdale Run Formation

To the right of the light colored band, the result of deep weathering along a dolomitic zone, is the Rockdale Run Formation. These dolomite zones repeat cyclically to the right throughout the remainder of the exposed stratigraphic section. Described (Root and Becher, 1981) as "medium-bedded, finely laminated to homogenous, chert-bearing micritic limestone and stromatolitic limestone" at this site no chert or stromatolites were observed.



View of southwest wall of quarry exhibiting south dipping layers in the Rockdale Run Formation containing layer parallel calcite veins with shear direction denoted by *en echelon* calcite veins.

Structurally, all quarry rocks are positioned on the north limb of an overturned anticline whose axis is located ~0.6 miles south of the contact photo (refer to LiDAR/geologic map for view of local structure). All rocks in the quarry are overturned dipping steeply to the south from 70 to 80 degrees.

Finely laminated layering in the Rockdale Run Formation

Sedimentologic features such as ripple marks are rarely observed in the fresh rock exposures. In the deeply weathered portions of the Rockdale Run Formation on the uppermost level very thin and finely laminated siliceous layers protrude from weathered surfaces. Fresh rock surfaces exhibit the fine laminations characteristic of this formation.

Calcite and Celestine are occasionally found in the Shippensburg quarry

Reference

Becher, A. E., and Root, S. I., 1981, Groundwater and geology of the Cumberland Valley, Cumberland County, Pennsylvania: Pennsylvania Geological Survey, 4th ser., Water Resource Report 50, 95 p. (also online at www.dcnr.state.pa.us/topogeo/pub/water/w050.aspx)

Mileage Interval	Cumulative Mileage	**STOP = Stop Sign; = Traffic Light; "T" = T Intersection; TR = Township Route; "Y" = Y intersection**
0.0	55.4	Return to PA Route 533 N
0.3	55.7	***Turn right*** on Brown Road (TR 328)
1.0	56.7	STOP ***Turn left*** onto US Route 11 N
5.7	62.4	PA 233 intersection; continue straight on US 11
10.3	72.7	PA 465 intersection; continue straight on US 11
3.0	75.7	PA 641 junction; continue on US 11
1.0	76.7	***Turn right*** on S. Hanover Street
0.1	**76.8**	***END* of Day 1 tour at Comfort Suites, Carlisle, PA**