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Stratigraphy and Structure of the Chilhowee Group in Lancaster and York Counties

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INTRODUCTION

Joseph Smoot

The Chilhowee Group in the Blue Ridge Province of eastern North America (Fig. I-1) consists of upper Neoproterozoic to lower Cambrian clastic sedimentary rocks deposited during the opening of the Iapetus Ocean (Rankin, 1975, 1976; Bond et al., 1984; Wehr and Glover, 1985; Fichter and Diecchio, 1986; Simpson and Ericksson, 1989, 1990; Faill, 1997; Tull et al., 1998, 2011, Smoot and Southworth, 2014). The Chilhowee Group was initially named for the basal Cambrian siliciclastic rocks exposed on Chilhowee Mountain in Tennessee (Keith, 1895). The stratigraphic names for rock units within the Chilhowee group changes considerably along the outcrop belt (Fig. I-2), but generally consist of a basal coarse-grained unit, overlain by a shale-rich unit, and capped by a coarse-grained unit. The basal rocks of the Chilhowee Group unconformably overlie Mesoproterozoic and Neoproterozoic rocks (e.g., King, 1964; Southworth and Aleinikoff, 2007; Southworth et al., 2009). Thermal ionization mass spectrometry (TIMS) U-Pb ages of xenotime overgrowths of detrital zircons in rocks 6 km stratigraphically beneath them (Ocoee Supergroup, Tennessee, Fig. I-1) indicate that those rocks are older than 570 Ma (Aleinikoff et al., 2006). Metarhyolite of the Mount Rogers and Catoctin Formations (Fig. I-1) yields a U-Pb sensitive high resolution ion microprobe (SHRIMP) age of 756 Ma (Tollo et al., 2012) and a TIMS age of 563 Ma (Southworth et al., 2010), respectively. Lower Cambrian ostracodes, brachiopods, and trilobites are in the middle part of the Chilhowee Group (Murray Shale, Tennessee; Walker and Driese, 1991); a glauconite grain yielded a Rb/Sr (Hurley et al., 1960) recalculated age of 539 ± 30 Ma (Walker and Driese, 1991). An *Olenellus* trilobite at the top of the Chilhowee Group (Antietam Formation; Walcott, 1891), and abundant lower Cambrian fauna in the overlying carbonate rocks (Tomstown Formation and Shady Dolomite), indicate that the rocks are older than 516.5 Ma (biostratigraphic reconstructions by Ogg et al., 2008). Thus, the Chilhowee Group is bracketed as 563-516 Ma, mostly lower Cambrian but locally upper Neoproterozoic, in the northern part of the outcrop belt, but the basal age is only constrained as younger than 756 Ma in the southern part of the outcrop belt.

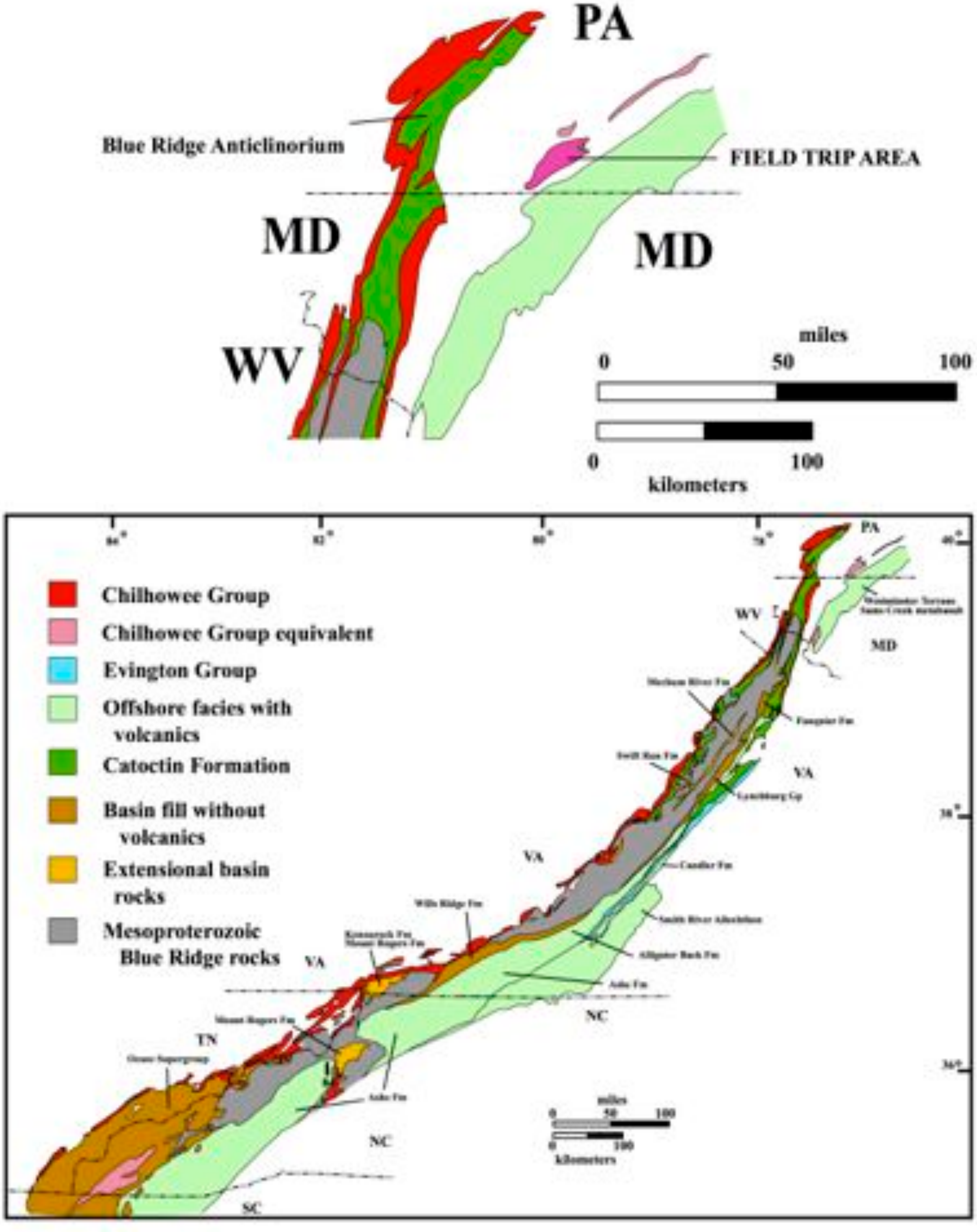

Figure I-1. Distribution of the Chilhowee Group in the Blue Ridge Anticlinorium and its equivalents to the east. Detail shows location of field trip area.

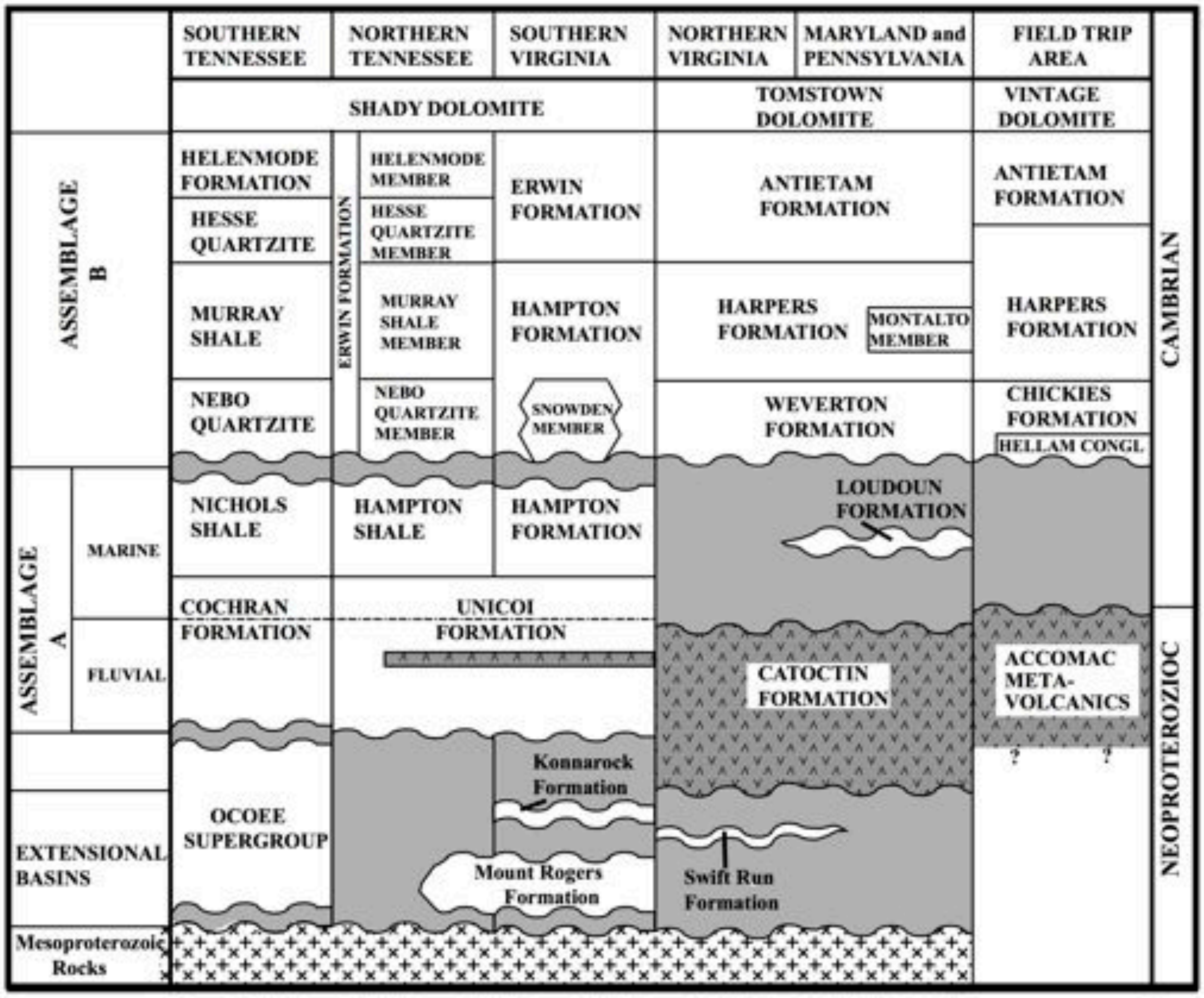

Figure I-2. Stratigraphic correlation of units within the Chilhowee Group based upon the model of Smoot and Southworth (2014). Catoctin Formation and Accomac metavolcanics are equivalent to Assemblage A below an unconformity. Gray areas indicate hiatus of unknown duration.

Smoot and Southworth (2014) present a model for the Chilhowee Group and stratigraphically adjacent units comparing them to volcanic rift margins similar to those observed in seismic profiles along the modern margins of the Atlantic and Indian Oceans (i.e. Mutter et al., 1982; Eldholm et al., 1987, 1995; Benson and Doyle, 1988; White and McKenzie, 1989; Oh et al., 1995; Jackson et al., 2000; Planke et al., 2000; Menzies et al. 2002; Elliott and Parson, 2008; Ajay et al., 2010). They envision two stratigraphic assemblages separated by an unconformity: the older package representing accumulation during the development of strata equivalent to seaward-dipping reflectors (SDRs) and the younger package representing buildup of the continental terrace (Fig. I-3). The Chilhowee Group in the field trip area unconformably overlies metabasalts and older metarhyolites. It is most likely that these strata are akin to the deposits in the northern Blue Ridge Anticlinorium with the metabasalts being equivalent to the older stratigraphic assemblage and the Chilhowee Group rocks entirely within the younger assemblage.

The field trip area is an eastern outlier of the Chilhowee Group outcrop belt separated from the Blue Ridge Anticlinorium by faults and folds. It is interpreted as an eastern facies of the Blue Ridge Chilhowee Group in the volcanic rift margin model (Smoot and Southworth, 2014). The Catoctin Formation in the VRM model was deposited as subaerial basaltic sheets that are the landward extension of SDRs. The model

predicts that eastern thrust slices should consist of subaqueous basalt sheets that are intercalated with marine shales. The metabasalts at Accomac are consistent with this prediction (Stop 7). The model also predicts that those basalts will have a chemistry closer to MORB than the subaerial basalts of the Catoctin Formation and that they will have a younger age. These predictions are based on a geometry where the eastern basalts represent younger offlap of SDRs in the late stages of rifting and intitial development of oceanic crust. The Chickies Formation in the field trip area represents the initial deposits formed after the rapid subsidence producing SDR's. These deposits are equivalent to the Weverton Formation in the northern Blue Ridge Anticlinorium that are dominated by marine nearshore environments. The Hellam Conglomerate Member may also be marine, but could also represent a fluvial episode on the developing continental terrace. Fluvial deposits that are erosionally overlain by marine deposits have been observed in the basal part of the Weverton Formation (Smoot and Southworth, 2014). The Harpers and Antietam Formations are similar to their counterparts in the Blue Ridge Anticlinorium, although the Antietam Formation in the field trip area is dominated by more offshore facies than the clean quartzites in the anticlinorium. This is also consistent with the geometry predicted by Smoot and Southworth (2014).

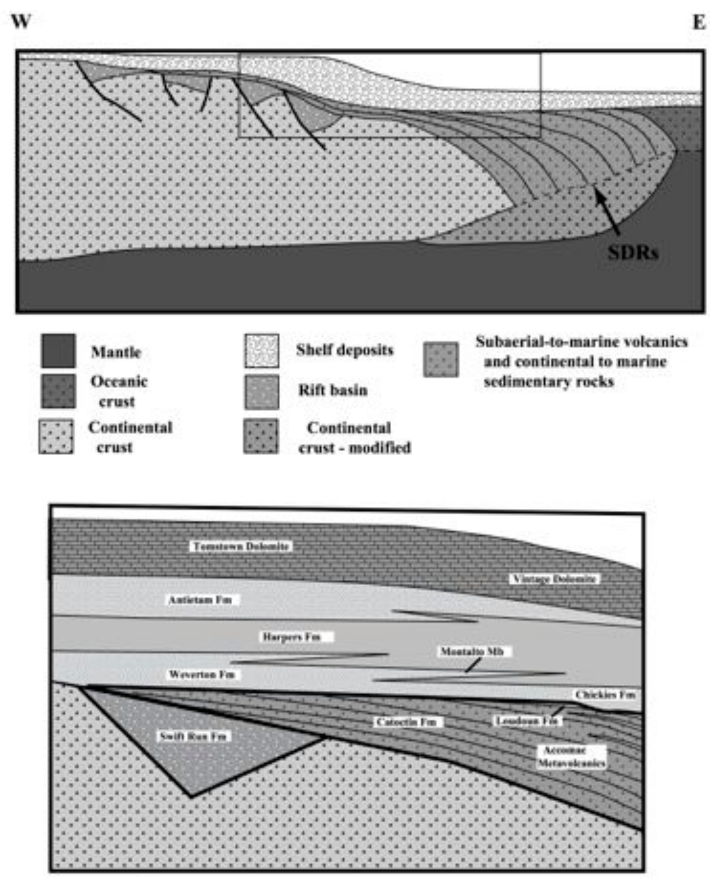

Figure I-3. A. Schematic sketch of a volcanic rifted margin based on seismic reflection profiles. The unit comprising seaward dipping reflectors (SDRs) rests unconformably on continental crust and rift deposits of subaerial flood basalts and fluvial sediments. These grade upsection and basinward into subaqueous basalts and marine sediments. Deposits of the continental terrace unconformably overlie the SDRs. Box shows distribution of features shown below. Based on cross sections illustrated in Jackson et al. (2000). B. Sketch showing distribution of stratigraphic units in the northern Blue Ridge Anticlinorium and the field trip area in context of the volcanic rifted margin model. The Hellam Conglomerate occupies an erosional depression into the underlying volcanic rocks.

STRUCTURE OF THE HELLAM HILLS

Jeri Jones

The metavolcanics, the Chckies, Harpers and Antietam formations are located with the Hellam anticlinorium. The regional trend is mostly N.60° E. From south to north, the folds include the Chickies Rock anticline, Mount Zion anticline, Accomac anticline, Dugan Run anticline, Dee Run syncline, Trout Run anticline and the Emigsville syncline. These folds are all overturned to the northeast and plunge toward the southwest. The metavolcanics are now exposed on the axis of the Mount Zion and Accomac anticlines. What makes the Hellam Hills more complicated is that these folds are cut by several thrust faults. The Highmount Overthrust displaces the Chickies Rock anticline and the Mount Zion anticline close to the Susquehanna River. These two anticlines could be one in the same prior to the faulting. The Glades Overthrust located to the north, disrupts the Dee Run anticline and the Emigsville syncline. For both of these overthrusts, the upper plate is on the south side. Finally, the Chickies Overthrust is found along the York County shoreline for five miles from the Codorus Creek eastward to a point just north of Chickies Rock. From here this overthrust turns east-northeast across the Susquehanna River and continues into Lancaster County. The Chickies Overthrust has brought the Hellam Hills Chilhowee rocks over the carbonate rocks to the north.

A small tribute to two early geologists who laid the foundation in the interpretation of this area's regional geology: George Stose, who was employed by the U.S. Geological Survey for many years, teamed up with Anna Stose, a graduate of Bryn Mawr College, who was among a long line of female geologists from this small educational institute in metro-Philadelphia. George and Anna conducted detailed mapping of this region, including the Hellam Hills, and produced several reports on their updated interpretations (Stose and Jonas, 1933; 1939; Stose and Stose, 1944). Although plate tectonics was not in the vocabulary at this point and structural concepts were primative in the early days, George and Anna's ideas have held up to the test of modern times. George and Anna were great as a scientific team and in 1938 they were married. Talk about a bibliography nightmare! Suddenly, Stose and Jonas (or Jonas and Stose on some reports) became Stose and Stose (again, some reports listed Anna first and some reports vice versa). In this respect, George and Anna's ideas have not stood the test of time—today Anna no doubt would retain her professional name.

George and Anna Stose recognized that the Hellam anticlinorium folds and the Highmount and Glades overthrusts were of a different age than the Chickies Overthrust. Part of their reasoning was the regional trend is N. 60° E. compared to the trend of the Chickies Overthrust which is west-east, supplying a control for the Susquehanna River's course west of Chickies Rock. Today, the folds and two thrusts are regarded as Taconian in age while the Chickies Overthrust is Alleghanian.

STOP 1. Breezyview Overlook, Chickies Rock County Park.

40º 02' 42.0" N 76º 30' 58.9" W

Charles Scharnberger

At this location, we get a good overview of the geomorphology associated with the Chilhowee Group where it is incised by the Susquehanna River, north of Columbia, PA (Lancaster County), and Wrightsville, PA (York County). The view in Figure 1-1 is looking west from Lancaster County to York County. The Chickies quartzite is the principal ridge-forming unit, stratigraphically lowest and farthest north (right) in this view. Often, the Harpers phyllite and Antietam sandstone (or quartzite, if you prefer), are interbedded so as to make mapping them as separate units difficult. However, here they are quite distinct, the phyllite underlying a valley and the sandstone making a ridge lower than the Chnickies Ridge. Farthest left is the York Valley, underlain by Cambrian carbonates. These carbonate units also occur to the north—off the right side of this photo—where they have been overthrust by the Chickies.

An interesting question is why the river suddenly turns south and cuts through the resistant Chickies quartzite at this point. The river's course may be antecedent or superimposed, but just west of the water gap, it flows eastward (or even slightly northeastward), apparently controlled by the quartzite. If it continued eastward for only another 15 kilometers or so, it could flow around the nose of the plunging Chickies anticline, thus taking the easiest route. One is tempted to postulate the presence of a cross fault or major fracture zone to provide relatively easy passage for the river. There is, however, no apparent off-set of contacts from one side of the river to the other.

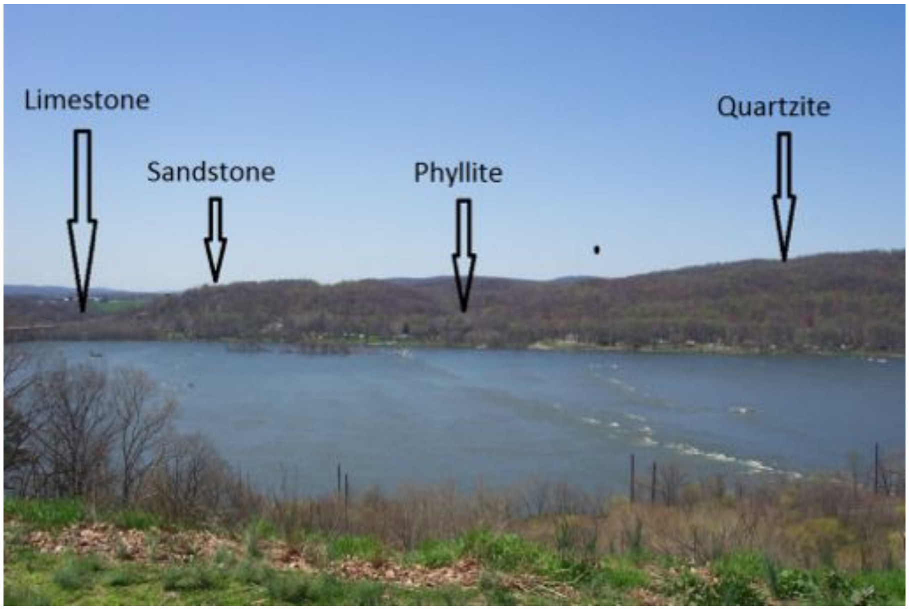

Figure 1-1. Geomorphic expression of the Chilhowee Group on the west shore of the Susquehanna River as seen from the Breezyview Overlook.

STOP 2. Chickies Rock.

40º 03' 16.4" N 76º 31' 27.9" W

Charles Scharnberger

Chickies Rock is an oft-visited outcrop of the Chickies Formation as exposed on the east side of the Susquehanna water gap. This is a favorite location for rock climbers, and has been the scene of several tragic falls from the top. (The top is easily reached via a path following an old trolley line accessible from a parking area on Route 441 just south of the deep road cut.) The face of Chickies Rock is not entirely natural, rock having been removed to accommodate first the Eastern Division of the Pennsylvania Canal System (remnants of which can still be seen here), and then the railroad. The 19th century naturalist and ironmaster Samuel S. Haldeman lived in a "mansion" at the base of the Rock. Haldeman, who corresponded with Darwin, first identified and named the trace fossil *Skolithos* at this location. *Skolithos* tubes can be observed at various places in the outcrop, and in talus blocks. Much better examples, however, will be seen at the next field trip stop.

A few buildings from one of the many iron furnaces that once lined the river's shore remain to the north of Chickies Rock. Several ruins of furnaces may be found along the path to the south. Ore was primarily limonite from the Grubb Mine a short distance to the east, and later from the large magnetite ore body at Cornwall, Lebanon County.

Recent windfalls of timber have made direct access to the north end of the outcrop difficult, so we will walk south on the old towpath/railroad grade to location 4 on the top cross section in Figure 2, and then work our way back north to location 1.

Structural features of Chickies Rock are discussed in detail by Wise (2010), and will be only briefly summarized here. The outcrop obviously is a large anticlinal fold, with several second-order folds and faults. This anticline has developed at the leading edge of the hanging wall of the Chickies Overthrust, in classic fashion. Along with smaller folds and thrusts to the south (see lower cross section of Figure 2), this may be considered a thrust duplex. Wise (2010) emphasizes that folding is accommodated primarily by "deck-of-cards" slip on bedding and cleavage planes, with relatively little internal strain, as indicated by *Skolithos* tubes that remain nearly perpendicular to bedding regardless of the mount of rotation experienced by the beds. Wise (2010) interprets the spaced cleavage as having formed by bedding-parallel shortening during the Taconian Orogeny. The Chickies thrust and fold are interpreted as Alleghanian features.

At location 4 is found an intriguing small outcrop displaying disharmonic folds. Look for "corkscrew lineations" due to Alleghanian folding of Taconian cleavage on the south face of this outcrop. Just to the north of this location, the footwall of a large normal fault—probably of Mesozoic age—marks the southern end of the main outcrop. Location 3 is a good place to observe "cleavage refraction," due to flexural slip along phyllitic beds.

Location 2 is a small cave developed at the hinge of a second-order faulted anticline. In its natural state, this cave was considerably larger and probably served as a rock shelter for Native Americans.

Location 1 is at the faulted, steeply dipping north end of the main outcrop. Note the linear ridges on the near-vertical north face. Traditionally, these have been interpreted as ripple marks, but an alternative interpretation is that they are the truncated edges of cross beds. Examine and decide for yourself.

Reference:

Wise, D.U., 2010, STOP #5: Structural features at Chickies Rock, in *Tectonics of the Susquehanna Piedmont*, Guidebook for the 75th Field Conference of Pennsylvania Geologists, pp. 49-57.

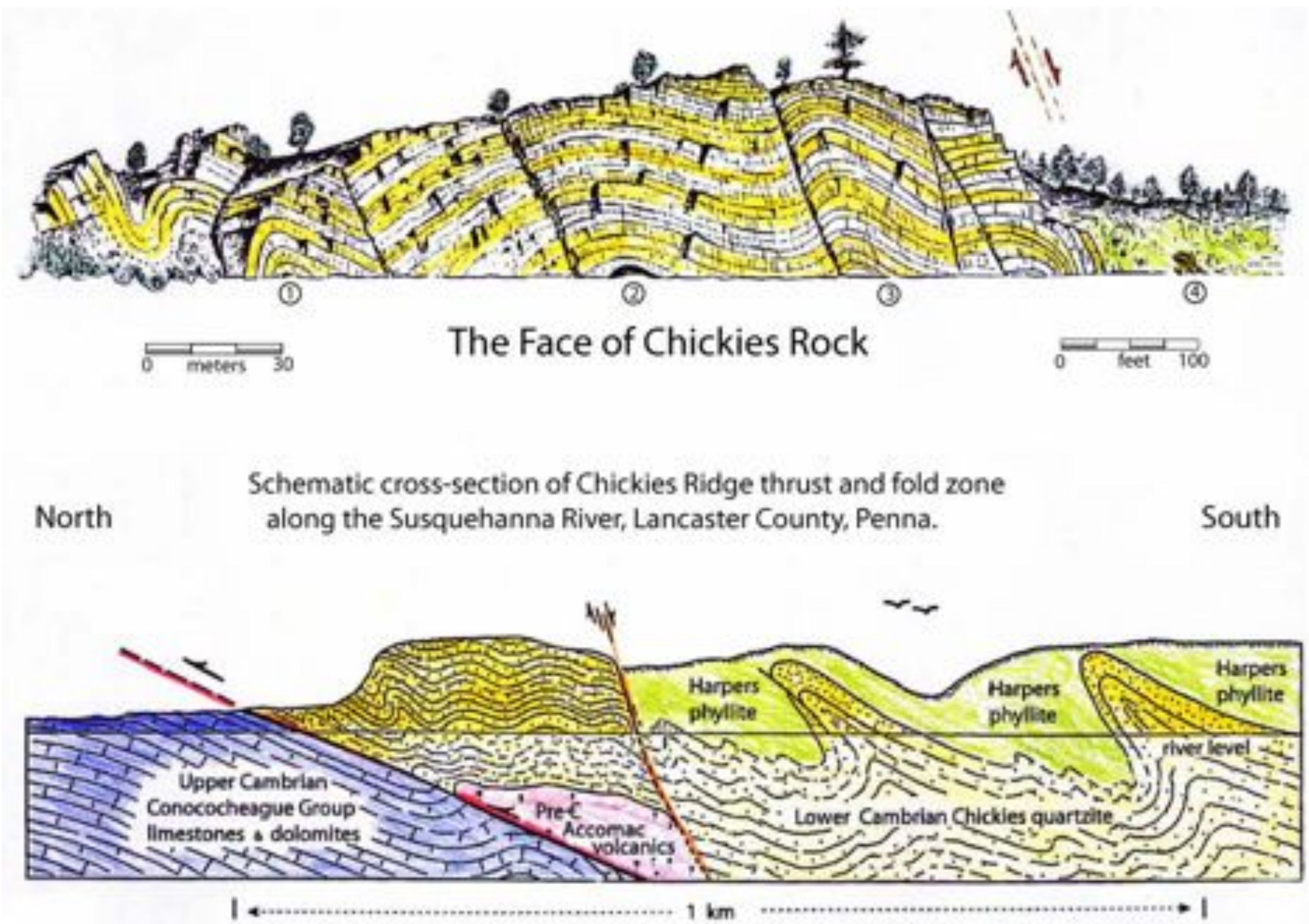

Figure 2-1: Cross sections at different scales of the main structural features on the east side of the Susquehanna River at and in the vicinity of Chickies Rock. This figure is reproduced (with permission) from page 50 of Tectonics of the Susquehanna Piedmont, Guidebook for the 75th Field Conference of Pennsylvania Geologists (2010).

STOP 3. York Silica Sand Quarry - The Chickies Formation

39º 59’ 35.7” N 76º 43’ 10.4” W

Ed Simpson

Physical Sedimentary structures

The Chickies Formation in the York Silica Sand Quarry is dominated by medium-to coarse-grained sandstones that display medium-scale trough cross bedding (Fig. 3-1A). The toughs cross beds are commonly modified by cross cutting *Skolithos* or *Monocraterion* tubes. In addition to the trough cross bedding is a low-angle inclined bedding sets (Fig. 3-1C and D). The low-angle inclined bedding set has mudstone drapes capping the cross beds (Fig. 3-1B). At least two thin sandstone beds are present in these mudstones (Fig. 3-1C).

Chickies Formation is best interpreted as marginal marine deposits (Goodwin and Anderson, 1974; Adams and Goodwin, 1975). Adams and Goodwin (1975) favored an estuarine depositional system. Goodwin and Anderson (1974) employed a tidal creek model with channel deposits recorded by the medium-scale trough cross beds and low-angle foresets with mudstone drapes and the interbedded fine-grained sandstone and mudstone facies reflected tidal ponds sedimentation. Since their original work, the significance of mudstone draping of foresets in recognizing a tidal influence has expanded significantly (Visser, 1980; Archer, 1998; Eriksson and Simpson, 2000; Davis and Dalrymple, 2012)

Trace fossil assemblage

Two types of trace fossils cross cut the primary cross bedding in the Chickies Formation. These are *Skolithos* and *Monocraterion*.

Skolithos

Haldemann named *Skolithos* in 1840. Numerous spellings are present in the literature, for example *Skolithos*, *Scotolithus*, Scolithus, and *Skolithus*. *Skolithos* is the proper spelling based on the Principle of Priority. The *Skolithos* trace consists of unbranched straight pipes developed perpendicular to bedding (Fig. 3-2A; Häntzschel, 1975). Tubes may be spaced from dense (pipe rock) to sparse (Fig. 3-2C). Diameters range from 1 to 15 mm (Fig. 3-2B; Häntzschel, 1975). Reported lengths are highly variable from a few centimeters to over two meters in length (Häntzschel, 1975; Schlirf and Uchman, 2005). Numerous species have been proposed often modifying the fundamental definition of straight tube (see for example Howell, 1944, 1945; 1955; 1958; Alpert, 1975).

Monocraterion

Torell (1870) established the *Monocraterion* ichnogenus. *Monocraterion* is describes a funnel-shaped structure with a straight tube in the center that may be slightly curved but is always perpendicular to bedding and never branched (Häntzschel, 1975). Funnel diameters are up to a few cm wide with a maximum length of 16 cm (Fig. 3-2D). In transverse section, the funnel consists of a series of concentric rings (Fig. 3-2D; Häntzschel, 1975).

Discussion

Skolithos is developed commonly in high-energy nearshore lattoral deposits (Droser and Bottjer, 1989; Drosier, 1991) and in shelf deposits (Vossler and Pemberton, 1988). The occurrence in shelf deposits suggests that *Skolithos* in storm-deposited sandstones recording burrowing opportunistic organisms colonizing the sands following storms.

The organism that produces the Cambrian *Skolithos* is unknown. Possible proposed trace makers have included polychaetes or phoronids (Alpert, 1974). The modern polychaete *Diopateria cuprea* has been proposed as a possible analog for *Skolithos-Monocraterion* (Barwis, 1985). Skoog et al. (1995) examined the distribution of *Diopatera cuprea* tubes across tidal flats near Wallops Island, VA. The vertical distribution could match the hypothesized vertical distribution of *Skolithos* (Goodwin and Anderson, 1974), but tube spacing does not correspond to either Cambrian or Silurian population statistics. Application of the nearest neighbor technique measures tube dispersion across a surface (Clark and Evans, 1954; 1979) tests to see if the distance between tubes is random. This statistic can then be used to glean information about feeding strategy hence yielding insight into the synecology of the producing organism (Pemberton and Frey, 1984). Pemberton and Frey (1984) examined bedding plane views of Cambrian and Silurian *Skolithos*. Cambrian *Skolithos* had R-values of 0.99-1.66; an R-value of 1 is a random distribution (Pemberton and Frey, 1984). Gourley and Key (1996) reports a mean value of 1.27 from the Mount Alto Member of the Harpers Formation in Pennsylvania. This range of R-values for Cambrian *Skolithos* demonstrates a uniform distance. Silurian *Skolithos* yielded R-values of 0.88 to 1.12 indicating a random distribution for the producing organism. R-values for the modern polychaete *Diopatera cuprea* vary from 0.20 to 1.73, with nearly all observations below 1. This R-value range signifies a clustered distribution. Even distributions are characteristic of organisms that maximize feeding distance between individuals. Organisms that do not interact with each other are defined by random distributions. Clustered tubes demonstrate that the organisms interact or are co-dependent on each other. Pemberton and Frey (1984) used the differences in values from the Cambrian to the Silurian to argue that different organism types produced *Skolithos* through geologic time. The *Diopatera cuprea* are carnivorous polychaetes and harvest food off the neighbors tubes, hence it is an ecologic advantage to have tubes in close proximity. The R-value statistics indicate that *Diopatera* cuprea is not a very good synecological analog for Cambrian *Skolithos* (Skoog et al., 1994).

Goodwin and Anderson (1974) in studying the Chickies Formation proposed a model for the distribution of *Skolithos* and *Monocraterion* (Fig. 3-3). In their model, *Skolithos* is distributed from the low-tide line, high energy transitioning into *Monocraterion* near the high-tide line, low energy. *Skolithos* and *Moncraterion* are absent from the pond flats and the subtidal channels. *Diapatera cuprea* mimics the vertical distribution of abundance of *Skolithos* in the Goodwin and Anderson model (Skoog et al., 1994).

Seilacher (1967) proposed that environments, hence depth controlled distribution of ichnofossils. He developed a series of depth-distributed ichnofacies. The *Skolithos* ichnofacies develops on high-energy shorelines with mobile sand substrate and contains both *Skolithos* and *Monocraterion*.

In must be noted that *Skolithos* has been reported from continental environments such as the Permian braided river deposits (Fitzgerald and Barrett, 1986), Triassic flood plains (Netto, 2007) and many other continental settings. In continental setting *Skolithos is* interpreted as an insect burrow (Netto, 2007). In addition Gregory et al., (2006) points out that the simple tube morphology can be generated by plants in high intertidal to non-aquatic settings and urges caution when applying *Skolithos* as a paleoenvironmental indicator without collaborating evidence.

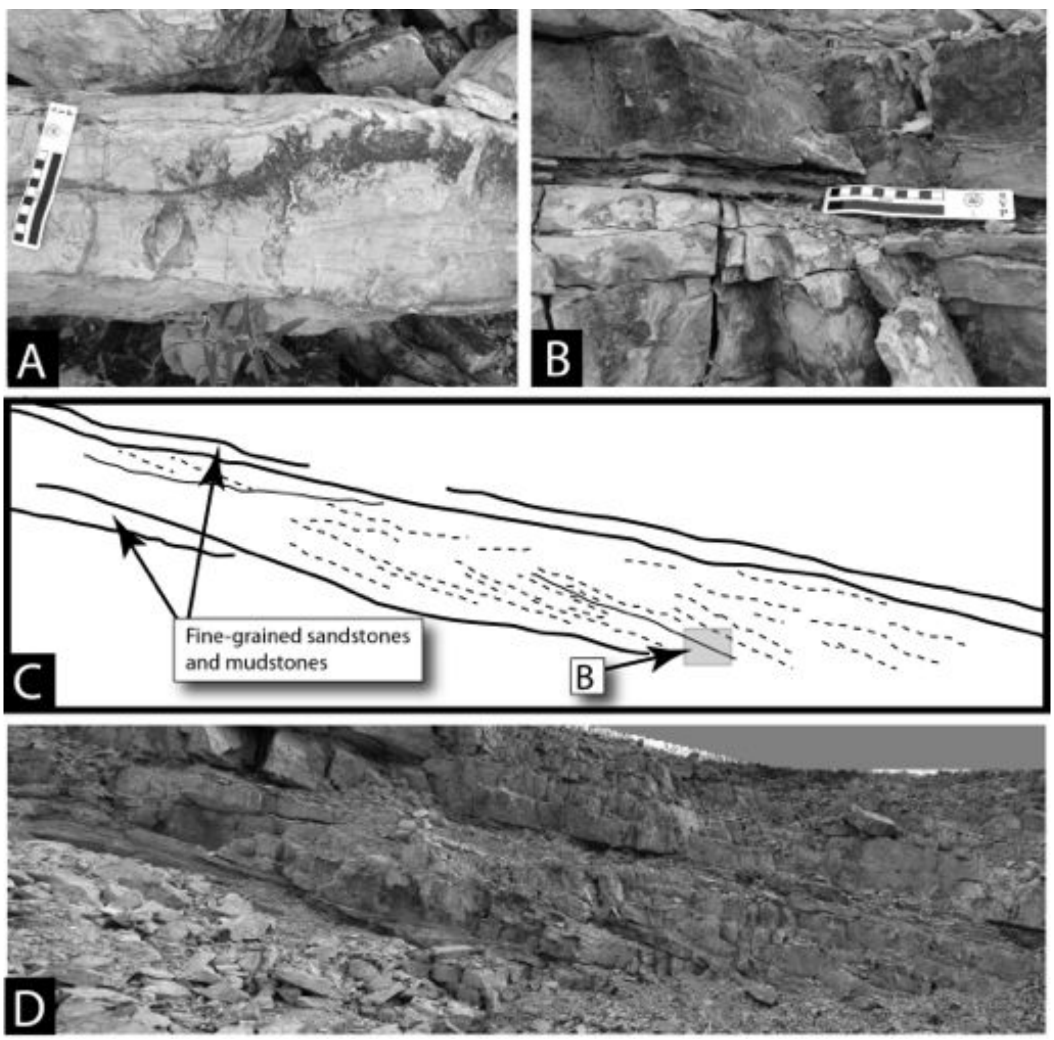

Figure 3-1. Field photograph of the York Silica Sand Quarry. A) Medium-scale trough cross beds. Scale is in cm. B) Thin mudstone and sandstone drape on low-angle foresets. C) Line drawing of D. The inclined cross beds set and interbedded fine-grained sandstone and mudstone facies distribution is shown. Thick black line are facies boundaries. Thin dark line is the position of thin sands and mudstone drape. Dashed lines are foresets. Shaded box shows the position of B.

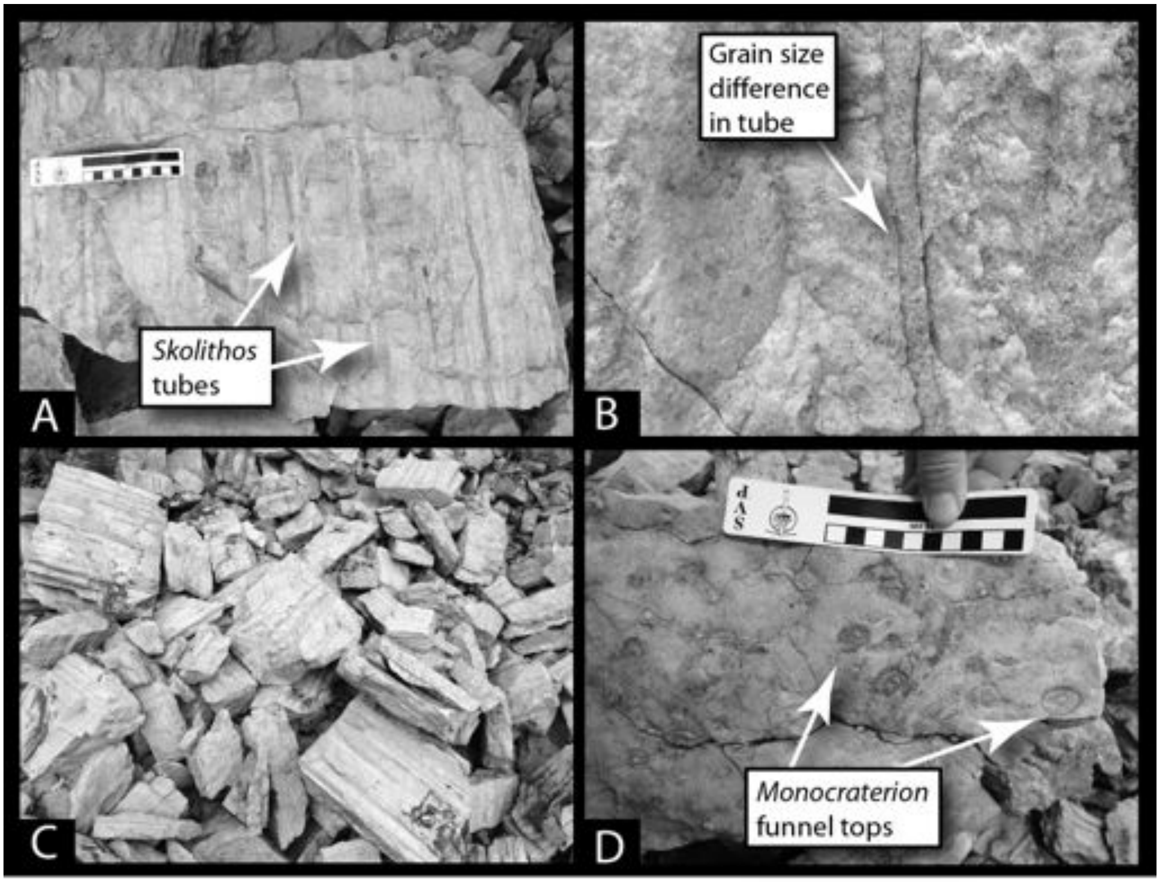

Figure 3-2. Field photographs of Skolithos *and* Monocraterion. *A)* Skolitho*s tubes. Notice the deflection of the foresets. B) Grain size difference between host sediment and the tubes. C) Quarry blocks of "pipe rock". D) Bedding plane view of top of the funnel-shaped* Monocraterion *ichnofossil. Note the center tube mimics* Skolithos. *Small subdivision of the scale is in centimeters.*

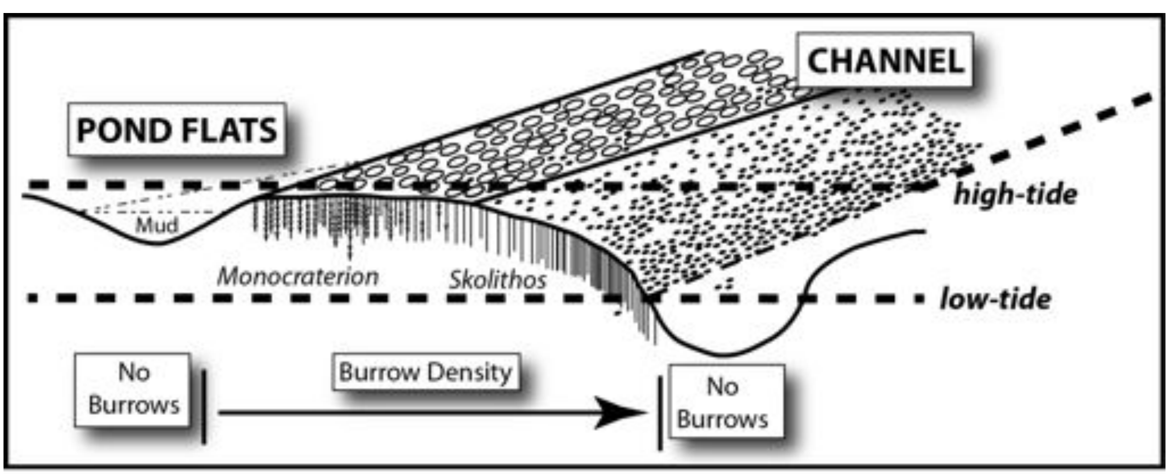

Figure. 3-3. Proposed paleoenvironmental model for the distribution of Skolithos *and* Monocraterion *(modified from Goodwin and Anderson, 1974).*

STOP 4. Blackbridge Road, York, PA- The Harpers/Antietam formations

39º 59’ 49.1” N 76º 43’ 30.1” W

Ed Simpson

The Antietam Formation consists of medium to coarse-grained sandstones with abundant *Skolithos*, very similar to the Chickies Formation examined at Stop 3, to the east across the river. The Harpers Formation is a predominately finer grained unit. In this area the absence of the typical Antietam Formation is resolved by grouping the two units together.

Physical Sedimentary structures

The Harpers/Antietam formations exposed along Blackbridge Road are dominated by bioturbated thinly bedded mudstones, siltstones and fine-grained sandstones (Fig. 4-1A). The common structure in slabs is unidirectional asymmetrical ripples, current ripples and thinly laminated sandstones. In outcropping and slabs, oscillatory ripples are preserved. Bedding is modified by an assemblage of cross-cutting invertebrate ichnofossils that vary in intensity that only vague bedding is preserved in the siltstones and mudstones (Fig 4-1-B, C, D and E).

These facies assemblage is best interpreted as highly modified distal storm deposits developed at or near the transition from storm-wave base to deeper depths is an outer shelf setting. The beds are composed mainly of turbidites generated from storm process (Simpson et al., 1993). Shelf sediments modified by oscillatory flow process have been documented by Myrow et al. (2002) and are present in the outcrop.

Ichnofossil assemblage

A diverse assemblage of ichnofossils are present in outcrop and in slabs. Ichnofossils tentatively identified include *Planolites* and *Paleophycus*. The absence of bedding planes in the outcrop precludes the separation of the ichnogenera into ichnospecies and the identification of traces such as *Rusophycus* and *Cruziana*, trilobite traces that are restricted to bedding planes.

Planolites

Nicholson (1873) named this ichnogenus *Planolites* for simple, unlined relatively straight, simple unlined burrows. The burrows are circular to elliptical in cross-section with diameters up to 1 cm. These burrows are filled with sediment different than the surrounding host sediment (Pemberton and Frey, 1982; Keighley and Pickerill, 1995; 1997)

Palaeophycus

The ichofossil *Palaeophycus* was named by Hall in 1847. *Palaeophycus* is similar to *Planolites* in that it consists of simple burrows, with circular to elliptical cross sections. They are separated from each because Palaeophycus is lined and *Planolites* is not (Pemberton and Frey, 1982; Keighley and Pickerill, 1995; 1997).

Discussion

These feeding traces are commonly developed in low-energy settings (Buatois and Mágano, 2011). The organisms that produced these traces are soft-bodied, probably polychaetes. In the Seilacher (1967) scheme, this Harpers/Antietam formation assemblage falls into the *Cruziana* ichnofossil assemblage that is deeper water than the *Skolithos* ichnofossil assemblage.

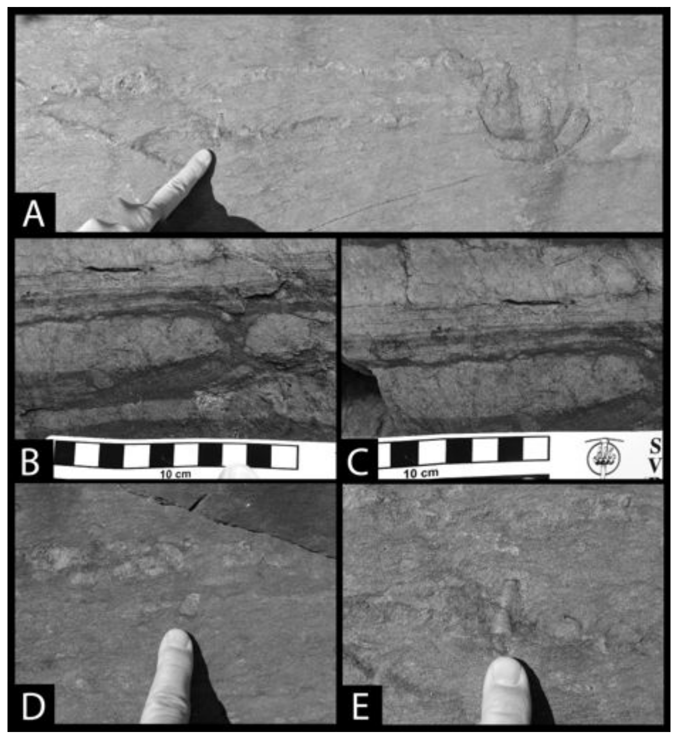

Figure 4-1. Field photographs of Blackbridge Road,. A) Medium-scale trough cross beds. Scale is in cm. B) Thin mudstone and sandstone drape on low-angle foresets. C) Line drawing of D. The inclined cross beds set and interbedded fine-grained sandstone and mudstone facies distribution is shown. Thick black line are facies boundaries. Thin dark line is the position of thin sands and mudstone drape. Dashed lines are foresets. Shaded box shows the position of B. Scale in B and C is in centimeters.

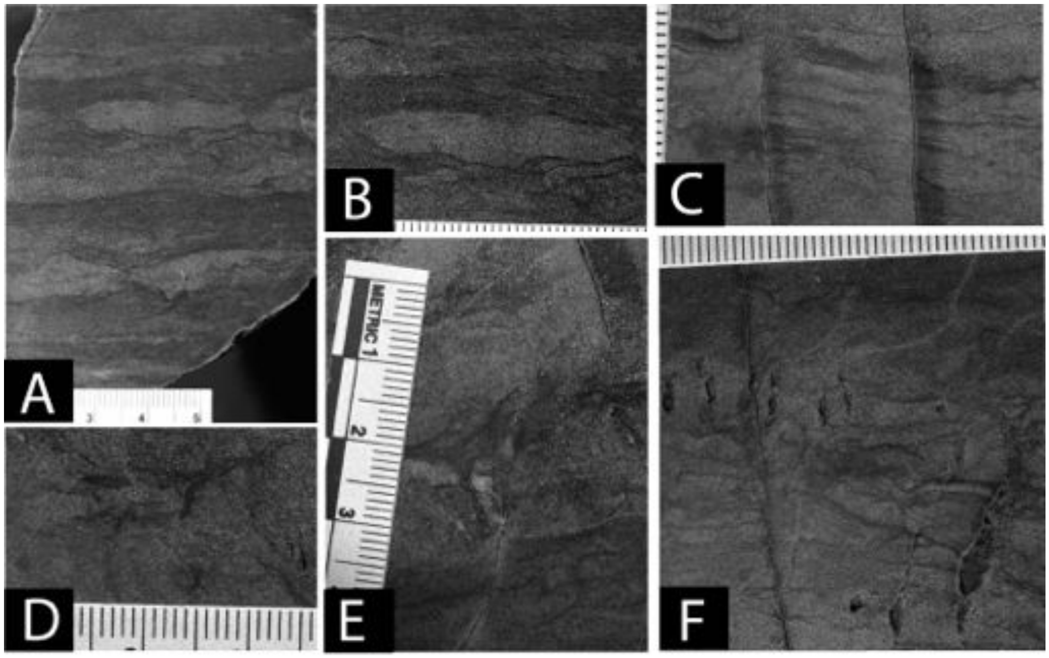

Figure 4-2. Cut slab photographs of interbedded fine-grained sandstones, siltstones and mudstones cross cut by Planolites *and* Palaeophycus. *A) Circles and ellipses of sandstone are* Planolites *burrows. B) Enlargement of A. C) Unidentified burrow feature cross cutting the sandstone bed on the left of the photograph. D, E and F) Mud-lined burrows are* Palaeophycus. *All scales are in millimeters. A and E show centimeter gradations.*

Stop 5. Rocky Ridge County Park: North Overlook, Oak Timbers Picnic Area: Hellam Conglomerate and Scenic Overlook

40° 00' 43.0" N. 76° 39' 12.6" W.

Jeri Jones

Questions to be considered here:

1. Just how far can you see from here?
2. How many physiographic provinces can be seen from here?
3. What are the pebbles in the conglomerate composed of?
4. Is the Hellam Conglomerate really a member of the Chickies formation?
5. What was the environment of deposition for the Hellam Conglomerate?

North Scenic Overlook: From this vantage point, a great physiographic picture of southeastern Pennsylvania can be seen. The diverse rock lithology of the area is reflected in the topography of the region. At this location, we are located 840 feet above sea level in the Uplands Sections of the Piedmont. For reference, north is toward the Three Mile Island Nuclear Power Plant near Middletown, Dauphin County. The flat-topped peak in the distance to the northwest is Ski Roundtop, a popular ski resort. This hill is underlain by Jurassic diabase located within the Gettysburg-Newark Section (GNLS) of the Piedmont. The ridge in front of Ski Roundtop also lies within the GNLS and is underlain with the Conewago Member (conglomerate and sandstone) of the New Oxford formation (Triassic),

The next prominent ridge to the east is underlain by diabase. This ridge terminates at the Susquehanna River north of Goldsboro, York County. On a clear day, the most distant visible ridge is Kitatinny Mountain (quartzite) of the Appalachian Mountain Section of the Ridge and Valley province (RVP). Pennsylvania's state capital , Harrisburg, would be seen in front of Blue Mountain if we could elevate the town about 100 feet. Harrisburg, Dauphin County, lies within the Great Valley Section (carbonates and shale) of the RVP. If you follow Kitatinny Mountain the whole way to the east, on a clear day, a gap can be seen in the ridge. This marks where Pa. Rte. 61 cuts through the ridge north of Hamburg, Berks County.

Three Mile Island sits within the Gettysburg Mesozoic Basin. To the east of Three Mile Island are three small peaks and a mostly-wooded ridge composed of Jurassic diabase. This ridge terminates in Elizabethtown, Lancaster County. To the right of Elizabethtown, a green water tank can be seen which marks the location of Mount Joy, Lancaster County. Carbonates of the Lebanon Valley sequence underlie this area. Another landmark located within the Lebanon Valley sequence is the white smoke stack of the Lancaster County Recovery Center in Bainbridge, Lancaster County.

Finally, to the east, you can see the wooded area of the Hellam Hills with the higher elevations composed of the Hellam Conglomerate and Chickies quartzite. Chimney Rock (STOP 6) is located close to the tall transmitter tower and "golfball" Dopler radar antenna.

Immediately in front of you toward the north, the rolling hills and wooded area are underlain by metamorphic rocks of the Harpers and Chickies formations. The Trout Run Anticline is found in the wooded area and the Emigsville Syncline is found to the northwest where you see mostly cultivated fields and development. The Glades Overthrust is found at the base of the hill paralleling Druck Valley Road where the Chickies quartzite is thrust up and over the Harpers Formation.

Exposures: The Hellam Member (Conglomerate) of the Chickies Formation is exposed on the higher elevations within Rocky Ridge County Park, Two good exposures are found on the hill east of the Scarlet Oak pavilion in the Oak Timbers Picnic Area and at the North Overlook about 400 feet west-northwest of Scarlet Oak. This is the best exposure of the Hellam Conglomerate on public lands in York County.

Here the rock is a coarse, pebbly, arkosic quartzite to a coarse feldspar-and-quartz pebble conglomerate grading, into a conglomeratic quartzite with a quartz and sericitic matrix. The conglomerate contains predominantly well-rounded milky white quartz pebbles 2 – 4 inches in diameter Some reddish, purplish and bluish quartz pebbles have also been observed (Stose and Jonas, 1939). Also, occasional angular dark fragments of the Catoctin metabasalt, metarhyolite and volcanic slate can be seen. There are purplish and greenish finer conglomerate beds and thin quartzose layers which assist in detecting bedding. The base of the Hellam Conglomerate is composed of a dark gray to black slate, not observed in the park (Stose and Stose, 1944). The conglomerate at the North Overlook has been moved downslope by erosion so the true dip is difficult to determine.

Fig. 5-1. The Hellam Conglomerate with two pebbles of metabasalt as seen at Rocky Ridge County Park.

Even with the descriptions of the Hellam Conglomerate by early geologists (Stose and Jonas. 1922, 1933, 1939, 1944; Jonas and Stose, 1926) no detailed analyses of the rock has been completed. A big question still exists as to whether the conglomerate's origin is fluvial or marine. Hyde (1971), Goodwin and Anderson (1974), and Adams and Goodwin (1975) state that the Chickies Formation sands and sediment were formed in braided streams and littoral zone along a coastal margin.

To take this one step further, and a good discussion for a fireplace chat, is if the Hellam Conglomerate really belongs to the Chickies Formation or not. It has been presumed that the conglomerate is the basal member of the Chickies; but could it be a prior unit of a different character? The true relationship between the conglomerate and the extremely immature, highly feldspathic quartzites may not be totally understood (Roger Thomas, personal communication, 2013).

A Jurassic diabase body known as the Stoney Brook dike traverses through the park just east of the North Overlook. This dike runs a distance of 38 miles from near the Mason-Dixon Line in York County northward to just northeast of Elizabethtown, Lancaster County. As exposed at the classic site just south of here in the York Valley, the dike is approximately 20 feet wide. Small pieces of diabase float have been observed on Trail #6 and in the power line right-of-way (Jones, 2008).

Regional Discussion: The Hellam Conglomerate occupies the higher elevations of the Mt. Zion Anticline, which is overturned to the northwest. The axis of the fold parallels the park road that we travelled to get to this stop. Quartzite of the Chickies Formation is found on the lower elevations of the park. The Highmount Overthrust and Glades Overthrust cut off the Chickies Formation on the south and north side of the anticline, respectively. The Hellam Conglomerate extends 3.2 miles southwest of here where quartzite of the upper portion of the Chickies Formation is found (STOP 3). The conglomerate extends along the regional trend in a northeasterly direction for about 2 miles following the trend of the Mt. Zion Anticline. Metavolcanics that unconformably underlie the Hellam Conglomerate are exposed on the axis of the Mt. Zion Anticline in the southeastern corner of Rocky Ridge County Park. The conglomerate is also found in the Accomac Anticline associated with the metavolcanics (STOP 7).

We will inspect the Hellam Conglomerate in the Accomac Anticline at STOPS 6a, b and c. Stose and Jonas (1933) and Stose and Stose (1944) give the thickness of the Hellam Conglomerate as 300-500 feet with a maximum thickness of 600 feet. The Hellam Conglomerate is not exposed continuously across the Susquehanna River, but is found associated with Mine Ridge and Welsh Mountain rocks 15-20 miles to the east. Jonas and Stose (1926) and Stose and Jonas (1933) have determined the thickness in that area at 150 feet or less.

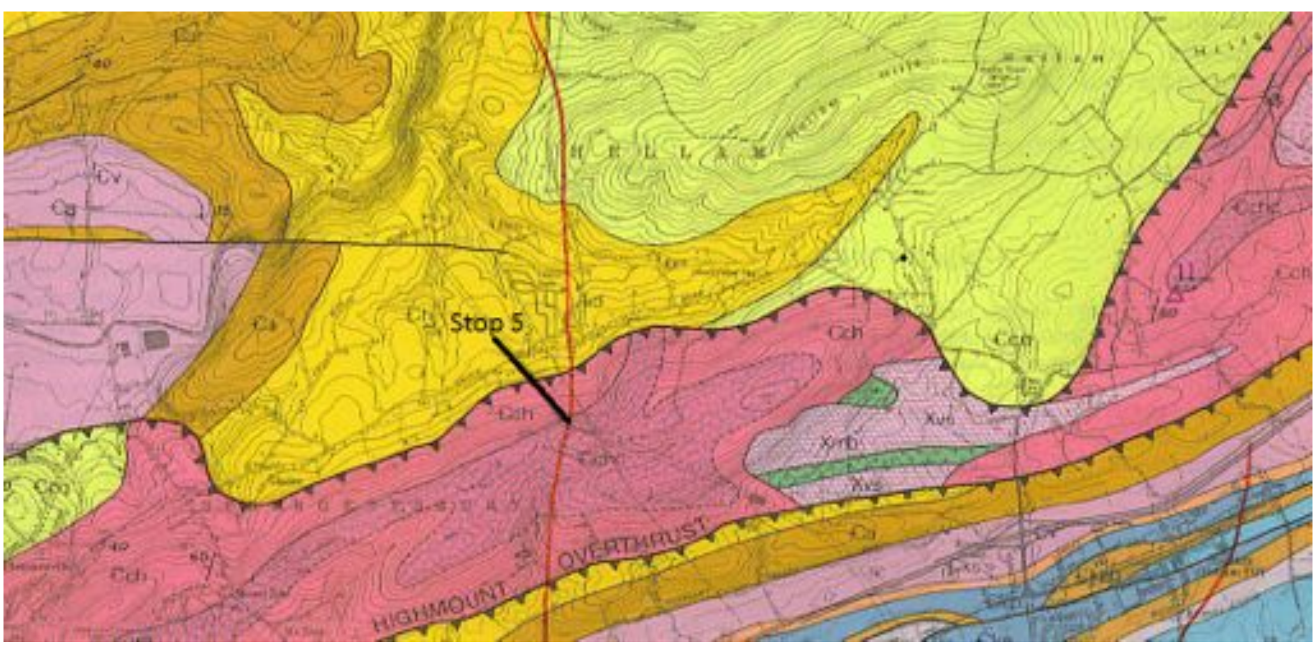

Fig 5-2. Geologic map of Rocky Ridge County Park from Wilshusen, (1979).
Cch – Chickies; Cchc – Hellam Conglomerate; Xvs – Volcanic slate; Xmb – Metabasalt;
Ch – Harpers Formation; Cv – Vintage Formation; Ca – Antietam Formation.

STOP 6 A, B, and C: The Accomac overturned anticline.

A: 40º 01’ 15.9” 76º 36’ 21.7”
B: 40º 02’ 00.7” N 76º 35’ 49.8” W
C: 40º 01’ 44.2” N 76º 35’ 16.3” W

Charles Scharnberger

At this three-part stop we will examine a mesoscale, overturned, plunging anticline with the Hellam conglomerate on its limbs, and the Accomac metavolcanics (STOP 7) in its core. Especially remarkable is the strongly developed spaced cleavage in the conglomerate, with flattened pebbles.

Substop A (Chimney Rock) is in the hinge zone of the fold, where strain is most marked.

Substops B and C are on opposite limbs of the fold. At one location, beds are right-side-up; at the other they are overturned. It is “left as an exercise” for you figure out which is which. (Hint: look for cross bedding and cleavage-bedding intersections.)

Figure 6-1. Chimney Rock, at the hinge of the Accomac anticline. Strongly developed spaced cleavage may at first be mistaken for bedding.

Stop 7. Accomac Road Cut: Metavolcanics and the Axis of the Accomac Anticline

40° 02’ 42.0” N 76° 33’ 48.7” W

Jeri Jones

Questions to be considered here:

1. Are there any original features remaining in the metabasalt?
2. What do the quartz-epidote pods signify?
3. Does this metabasalt belong to the Catoctin formation of South Mountain?
4. What other metavolcanic rock is found in the vicinity?
5. How did these metavolcanic rocks get here?

Location, location, location: Two geological factors have come together to allow us to inspect the eastern-most exposure of Catoctin (?) metavolcanics. First we are on the axis of the northwest overturned Accomac Anticline which brings the oldest rock known in the Hellam Hills to the surface (Stose and Jonas, 1933; 1939). Secondly, the Alleghanian Chickies Overthrust and the Taconian structures of the Hellam Hills intersect just off the shoreline of the Susquehanna River here. From here, and continuing 5 miles upriver, the Chickies Overthrust has brought the Hellam Hills strata over the carbonates of the lowlands to the north. The Susquehanna River has found its channel in the Chickies Overthrust until it makes a sudden and unpredicted turn to the south around Hellam Point. Also, the relative softness of the metavolcanics compared to the Chickies formation rocks has produced the Accomac Gorge, the only accessible point to the river in this area.

The Rocks: The nearly 800-foot long road cut contains the best exposure of the metabasalt in York County. The rock ranges from greenish to bluish-gray in color. Although most of the rock is massive, there are also some phyllitic metabasalts. The rock is composed of actinolite, chlorite, epidote, albite and quartz (Smith and Barnes, 2010). Notice at either end of the road cut are quartz-epidote filled amygdules. These amygdules appear to be absent in the middle section of the road cut. A trace of copper has been observed in these amygdules, which may be remnants of pillow lavas. Possible pillow lavas and pahoehoe toes can be seen along the bottom of the exposure. One particularly good specimen of pillows can be seen in a large piece of float leaning against a road sign about half way up the road (Fig. 7-1). Better examples of these structures have been observed in the metabasalts on the hillside to the west (Jones, 2000).

Fig. 7-1. Pillow lava exposed in float from the Accomac road cut. Note Brunton compass on right side for scale.

Also observed in the northern section of the road cut are stretched amygdules and rock fragments. Most of these are best seen along the top of the exposure. Also notice that the metabasalt in the northern section of the roadcut is phyllitic. The cleavage dips 37° in the direction S.40°E. Several prominent joints strike N.5°E. and N.55°E. Toward the southern end of the exposure, check out the fibrous veins in the metabasalt. This is apparently chrysotile (Fig. 7-2).

Fig. 7-2. Specimen of chrysotile found at Accomac.

Metabasalts also form the scenic stream gorge on the west side of Accomac Road (Fig. 7-3). Although the rock bed is not evident due to the running water, nice potholes have been formed. Throughout the Lower Susquehanna River Valley, the tributaries into the river have a reverse profile, meaning their gradient increases as it comes to the main channel. This probably is a result of the tremendous erosion that occurred with the Susquehanna River at the conclusion of the last Ice Age. The tributaries were not able to down cut as rapidly as the main river.

Fig. 7-3. Accomac Run flowing over South Mountain metabasalt on the west side of Accomac Road. Photograph is looking southwest on the axis of the Accomac anticline.

If you follow the stream toward its headwaters in a southwestern direction a short distance, pinkish to light reddish metarhyolite will be encountered, also marking the axis of the Accomac Anticline. Severely sheared metarhyolite may also exist toward the top of the Accomac road cut (Smith and Barnes, 2010). Stose and Jonas (1933) believe that the metarhyolite overlies the metabasalt in the Hellam Hills. The Catoctin Metarhyolite has been dated by Aleinikoff and others (1995) at 564 +/- 9 Ma. Southwortth and others (2009) report 571 Ma for a lower Catoctin Metarhyolite in Virginia and 564 +/- for an upper sample in Pennsylvania.

The only other possibly Catoctin metavolcanics in the vicinity are situated within the Pigeon Hills, a highland found in western York County and eastern Adams County, near Hanover and Abbottstown. Metarhyolite is apparently absent from the Pigeon Hills. The Pigeon Hills metabasalt has been considered to be a direct continuation of Catoctin metabasalt across the dividing Gettysburg Mesozoic Basin. It is likely that it is continuous beneath the basin (Smith and Barnes, 2010).

New Thoughts: The 75th Field Conference of Pennsylvania Geologists in 2010 used this location as one of its stops. Several new thoughts were offered as part of that discussion which included:

1. Bob Smith and John Barnes introduced a reclassification of the Catoctin metabasalt. Using the Tunnel Hill-Jacks Mountain fault system located in South Mountain of Adams and Franklin Counties, Pennsylvania, as a boundary, based on structural fabric and geochemistry, these rocks can be labeled as the Catoctin metabasalt to the south and the South Mountain metabasalt to the north. Each metabasalt represents a distinct phase of rifting of Rodinia. The rock exposed at Accomac might best be considered South Mountain metabasalt. All of the metabasalts within eastern Pennsylvania are related to one of the six stages of a rift-to-drift model.

2. Donald Wise explained a possible existence of the Accomac Volcanics as being associated with the Lancaster Transform Fault. This structure "was linked with another transform fault, now buried, displaced, and of uncertain location but still reflected in the chip of its edge now preserved as the Reading Prong in eastern central Pennsylvania."

The Great Unconformity: It has been a long-time understanding or belief that an unconformity exists between the metavolcanics and Chilhowee group. Every published report written about an area containing these two rock units describes the unconformity. It also marks the end of Rodinian rifting and the early stages of the ocean migration, eventually building of a continental margin and the appearance of early life. Nowhere in southeastern Pennsylvania is there a clear exposure of the unconformity. In 2000, Jones and Scharnberger searched for the unconformity on the property of Wizard Ranch Boy Scout Reservation on the west side of Accomac Road, and believe that they came with about 75 yards (65 meters) of finding the contact (Jones, 2000). With the release of a paper by Peters and Gaines (2012) proposing the idea that the Great Unconformity may have acted as a trigger for the Cambrian life explosion, interest in studying this relationship in South Mountain and Piedmont of Pennsylvania has again gained interest.

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mb – Metabasalt mr – metarhyolite vs – volcanic slate
Cch – Chickies Formation Cah – Antietam & Harpers Formation undivided
Cv – Vintage Formation Cl – Ledger Formation Ck- Kinzers Formation

T Thrust fault – T is on upper plate North is up

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