Correlating the “Fulton Site” within the Gettysburg Basin

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Abstract

The Fulton Site, a recently discovered fossil locality, lies within the Gettysburg Basin in the Newark Supergroup. Though this site has produced several vertebrate and invertebrate trace and body fossils, it has yet to be correlated stratigraphically. Regarding the issue of which Formation the Fulton Site lies in, there are currently two leading hypotheses. The first is that the site represents the New Oxford Formation (a fluvial unit), and the second is that it lies in the Gettysburg Formation (a lacustrine unit). Another issue is that of age, which has been confused with lithostratigraphy in the past. The hypothesis tested in this study is that the site lies in the New Oxford Formation, and that it is Carnian in age. In order to test these points, the rocks are characterized and depicted in a measured section. The site comprises red siltstones and black shales, representing a lacustrine environment. The fossil material was dated to try to constrain an age for the site. Some fossils, like the plants from a nearby site, were narrower in age range, and therefore more useful in aging the site, than other body or trace fossils. Using all the available information the most specific age that the site can be placed at is between the Carnian and the Norian. Regional maps were examined to further explore the locations of the New Oxford and Gettysburg Formations in nearby quadrangles. Along with the strike and dip measurements this study found that the boundary between the formations lies East of the Fulton Site, leaving the site itself in the Gettysburg Formation.

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Introduction

Background and Hypothesis

The Triassic Period was a time of great change in the history of the Earth. Geologically, the supercontinent Pangea was rifting apart along what would be the eastern North America coast. As the rift basins opened, the local and regional environment shifted. A shift was also occurring in the planetary biota. The late Paleozoic non-mammalian synapsids (e.g., dicynodonts) shared the land with a diversity of crurotarsan archosaurs that radiated in the Triassic, as well as the early dinosaurs, mammaliforms pterosaurs, and turtles (Benton 1993).

This period ended in a mass extinction that abated this diversity, but consequently allowed for many lineages to radiate into vacant niches. Currently, there are debates on the cause and timing of this extinction event. Some paleontologists hold that the mass extinction was actually two events, one at the end of the Carnian (220 Ma), and one at the Triassic-Jurassic boundary (199.6 Ma), with each event diminishing a specific part of the fauna (Benton 1993), while others claim that the entire extinction occurred at the Triassic-Jurassic boundary (Olsen 1999). Still others think that the timing was more gradual, lasting several millions of years. The mode is also widely debated, with some supporting the Central Atlantic Magmatic Province hypothesis (a flood basalt associated with the rifting of Pangea, lasting a few million years and covering seven million square kilometers of land with lava) (Olsen 1999, Olsen 2003), while others think that the meteorite responsible for the Manicouagan impact crater was also responsible for the extinction (Fraser 2006). The timing of these events is critical to understanding the faunal turnover, and the Triassic Period in general.

The process used for correlating geological events is stratigraphy. Fortunately, the Newark Supergroup provides a nearly continuous record of rock, starting in the Middle Triassic and continuing into the Early Jurassic. The Newark Supergroup is a set of sedimentary and volcanic rocks preserved in 29 paleo-rift basins in eastern North America (Weems 1997). The rift basins are the half-grabens that opened as Pangea split, and extend from Nova Scotia to South Carolina (Huber 2003, Lucas 2003). Even though the Newark Supergroup had been relatively well studied in New Jersey and Virginia, Maryland's outcrops of the Supergroup have not.

Recently, a site was found approximately ten miles away from Gettysburg, Pennsylvania in Rocky Ridge, Maryland, in which several researchers have started paleontological studies. This site is known to lie within the Newark Supergroup, and is hypothesized to sit on either side of the Carnian – Norian boundary, which as previously stated, could have implications for the extinction event in the Late Triassic. Figure 1A is a satellite map of the site. The site comprises red beds with sedimentary structures such as trace fossils (*Gwyneddichnium* trace fossils and insect trackways) and mudcracks, and lake beds with conchostracans (brine shrimp) and fish. This site, which was dubbed "the Fulton site," after the discoverer Richard Fulton, has not yet been stratigraphically dated. By measuring the stratigraphic column of this site, it will be easier to characterize the rocks, and determine how they correlate with the Late Triassic stratigraphy of the region.

There are two stratigraphic hypotheses pertaining to the Fulton site. The first says that the site correlates to the upper New Oxford Formation based on conchostracan index fossils (Kozur and Weems 2007). Paul Olsen holds the second hypothesis, which is that the site correlates with the lower Gettysburg Formation (Olsen, unpublished). My hypothesis for this project is that the site lies in the New Oxford Formation. Figure 2 is the stratigraphic column of the Newark Supergroup that shows the relative stratigraphic position of the New Oxford and Gettysburg Formations.

Previous Research Problems

There have been several issues that have come up during this project that have to do with past research of the Gettysburg Basin. The first is the way the basin was geologically mapped. G. Stose and F. Bascom were the first to publish on the area in 1929, in which they defined several of the formations of the basin (Stose and Bascom, 1929). What they did not do, however, is clearly specify a single type section and criteria for the boundary. When they defined the formations, the type section they used was not at a single, mappable spot. Instead, they used a composite section, for which locality information was not provided. A decade later, in 1938, A. Jonas and G. Stose published a map of Frederick County (Jonas and Stose, 1938). This is the first, and only, geologic map that includes the location of the Fulton Site. Even though this map is a good approximation of the location of formations, their map was not to today's standards: i.e., taking strike and dip measurements on point bars, and other surfaces that were not accurate, etc. However, this map places the Fulton Site clearly in the Gettysburg Formation. The next, and most recent, map of the area is the 1953 Maryland Geological Survey Rocky Ridge Quadrangle (revised in 1988), and even though the Fulton Site is in the quadrangle directly north of this one, and not located on this map, I have found this map to be the most helpful (Edwards 1988). On this quadrangle is mapped a syncline, which I will discuss further in my Data section.

The second is the published stratigraphic columns of the Gettysburg Basin. One of the difficulties with the production of stratigraphic columns of the area is that, not only were the formations poorly defined, but also the boundary between the formations is time transgressive (Smoot, 1991; Faill 2003**)**. This is a function of the paleoenvironments in which the formations formed. As the rift basins opened, the environments shifted and overlapped, causing the lithological boundary to shift (Faill 2003). More specifically to this project, the New Oxford Formations represents a fluvial environment, with cross-bedded sandstones and channel deposits. The Gettysburg Formation represents a shift to a lacustrine environment, with mudcracked siltstones and gray shales (Faill 2003).

An issue of special significance is the tendency of previous authors to conflate rock unit identity with age. In other words, some researchers have described the fossil content of the site and based on that information placed the site in a lithologic unit, instead of an age. The main issue here is that fossils describe ages, not lithologic units, and in recent publications this has been forgotten. Lastly, different authors have published alternative stratigraphic columns of the Gettysburg Basin, showing the boundary between the New Oxford and the Gettysburg Formations at different points in time (see Smoot 1999 and Faill 2003 for examples of stratigraphic columns). This may reflect an increase in the data used to produce the columns, thereby becoming more accurate, or just a change in popular ideas of the time.

Experimental Design

In order to measure a stratigraphic column I used a Jacob's staff and a Brunton compass. The staff was a 1 m tall, 3.1 cm in diameter wood dowel, which was cut by hand with a manual saw. The tick marks on it were spaced .10 m apart, and marked with black permanent marker. The Brunton compass was a standard azimuth Brunton.

Figure 3 depicts the experimental procedure for measuring a section. I set the Brunton's clinometer to the dip of the bed at which I was standing. This has an error associated with it (see Appendix 2 for comprehensive error calculations and discussions). To get the error of the dip, I measured it at 10 different points along the bed. I did this along two separate beds. The standard deviation of the first bed is 1.64 cm and for the second bed it is .91 cm (Appendix 2: Table 1). I used the bigger of the two standard deviations to be safer in my error estimates.

Once I set the clinometer, I placed the Brunton on top of the staff (holding it with my thumb and forefinger), with the sight piece towards me, and the mirror facing the compass (so that I could read the clinometer). I then tilted the staff until it was perpendicular to the beds, to level the clinometer. Then I had to site through the compass (through the eye hole on the black sight piece, and through the hole in the mirror) to the next point, which was stratigraphically one meter above the point at which I was standing. There is an error associated with this, as well, which I measured the error by sighting from a bed to one meter above that bed ten times, and measuring the variation in vertical distance between the original point and the new point in centimeters. I did this twice, using different starting beds each time. The average variation for the first set was 1.6 cm, and the standard deviation was 2.07 cm. The second set had an average variation of 5.7 cm, and a standard deviation of 4.16 cm (Appendix 2: Table 2). Again, I used the bigger of the two standard deviation measurements for my error.

When I had my point, I marked the bed with a rock cairn or an "X" in permanent marker. I was not able to put any stake or rebar marker because the rock beds are inside a horse enclosure, and I did not want them to get injured. Also, permanent marker is better than rock cairns because the horses can just kick the cairns over, but they cannot erase the marker.

Once the point was marked, I walked up the meter slowly, looking for any sedimentary structures, body fossils, or trace fossils. I also walked laterally, along strike, examining the exposed surfaces for similar features. I took samples of rocks and fossils (when present) for further examination and identification.

The second portion of my project used the column I measured to correlate the site stratigraphically. I identified the lithologies on the site by gross observation and hand lens analysis and compared my results to the operational definitions of the New Oxford and Gettysburg Formations to discern where in the sequence the site lies. The New Oxford Formation is an arkose conglomerate with red sandstones, siltstones, and shales, though it is mostly feldspathic sandstone. The Gettysburg comprises red fine- to medium-grained sandstones and shales, with conglomerates towards the top. The color of the Gettysburg varies from red to green, grey, and white (Glaeser 1966, Faill 2003). I also used the body fossils (conchostracans and fish) and ichnofossils (*Gwyneddichnium,* Figure 4) to help constrain an age for the site.

There were two neighboring sites that provided more information for this study. The first was a small outcrop, which yielded fossil plants from sediments that resembled those of the lakebeds at the Fulton Site. I analyzed the identity of these plants and sent for support from a paleobotanist (Brian Axsmith, University of Southern Alabama) specializing in Triassic flora in order to possibly retrieve an age for the sediments (see the Data section for more detail). The second site was a nearby railroad cut that contains both the New Oxford and Gettysburg Formations, which was not only the main point of comparison to the Fulton site, but also an anchor point for the boundary between the formations (Weems, pers. comm.). The proximity of the sites is seen in Figure 1B.

In addition, strike and dip measurements were taken with the Brunton compass at many points at the Fulton Site and the neighboring sites in order to determine if there were any structurally anomalies. Lastly, an exhaustive survey of accessible outcrops within an approximate three-kilometer radius of the Fulton Site was undertaken with the purpose of examining the local geology.

Data

Stratigraphic Column

See Figure 6 for the complete measured section of the Fulton Site. The measurements taken (as described above) were used to create a depiction of the section seen at the Fulton Site in Adobe Illustrator CS3. The section shows a shift in paleoenvironments from one that was subjected to periodic flooding and desiccation (as seen by the trace fossils and mud cracks) to one that was continuously underwater (evidenced by fish fossils).

Structure

The strike and dip at the Fulton Site varies only a few degrees throughout the site. The strike is between 350° and 355°. The dip varies between 20° and 25° SW. North of the Fulton Site is the plant site, whose strike is 295° and dips at 22° SW. The railroad cut is south of the Fulton Site and its strike and dip are 5° and 17° NW.

Fossils and Their Ages

In the red siltstones of the Fulton Site there are *Gwyneddichnium* trace fossils that are aged to the Late Triassic (Paleobiology Database). It is thought that the trackmaker is the reptile *Gwyneddosaurus erici*. There are three potential ichnospecies: *Gwyneddichnium majore, G. minore*, and *G. elongatum* (Bock 1952). The fish fossils that have come out of the lake are only identified to the genus level, so they cannot be used to date the site. The conchostracans from the lake are identified to come from the mid-Carnian (Weems and Kozur 2007). The plant remains from the paleobotanical site were compared to plants from B. Cornet's dissertation from 1977, and based on gross leaf morphology (shape, size, vein pattern, etc.) identified to be *Pagiophyllum diffusum*. This result was confirmed by B. Axsmith, a paleobotanist from the University of South Alabama (Axsmith, pers. comm.). This plant is from the *Dinophyton* zone (Ash 1980), and is dated to the late Carnian (Cornet 1977). See Figure 5 for photographs of sample plant material. On a final note, a small piece of heavily eroded vertebrate bone was found in the float of the upper red siltstones. No analysis has yet been completed on this bone.

Local Geology

Even though the boundary between the New Oxford and the Gettysburg Formations is clearly visible at the railroad cut, it is difficult to find elsewhere in the area. This is due to a diabase intrusion from the Jurassic that overlaps the boundary on the surface North of the railroad cut (Smith 1975). Also, soils developed over most of the outcrops, so they are limited to road and stream cuts. Several excursions were required before the contact was found approximately two miles North of the Fulton site.

Discussion of Results

Lithology of the Fulton Site

The Fulton Site comprises red siltstone with several beds containing mudcracks, raindrop marks, and trace fossils, all showing periods of flooding and rapid desiccation. These beds give way to lakebeds further up section that include the conchostracan and fish fossils that were discussed above (Kozur and Weems 2007). All these lines of evidence establish that the Fulton Site is in the Gettysburg Formation. If the site were in the New Oxford Formation, then there would be crossbedded sandstones and other fluvial sediments.

The strike and dip measurements that I gathered of the Fulton Site and neighboring outcrops give evidence towards there being a syncline. This is also shown in the Rocky Ridge Quadrangle, which, as mentioned above, is the quadrangle directly south of the one that contains the Fulton Site (Edwards 1988). By tracing this contact onto the Fulton Site quadrangle and using the synclinal pattern, I have been able to infer that the contact should lie to the East of the Fulton Site, leaving the site itself in the Gettysburg Formation. By searching for the contact where it supposedly intersected public roads, I was able to find it North of the site, exactly where I had inferred its location. This solidifies a second anchor point for the contact: the first at the railroad cut, and the second at the public road, further corroborating the Gettysburg Formation as the site's lithostratigraphic identity.

Age of the Fulton Site

As mentioned above, there are three primary sets of fossils that were found on or near the site. The first is the trace fossil *Gwyneddichnium*, which is dated to the Late Triassic (Paleobiology Database). The second are the conchostracan body fossils that are thought to be from the mid-Carnian (Kozur and Weems 2007). This is the only published interpretation of the biostratigraphy of the site and is only preliminary. As Kozur and Weems mention,

> "The two conchostracan horizons within the New Oxford Formation have proven exceptionally difficult to place stratigraphically. The Fulton site, in Maryland well to the southwest of the type area of the New Oxford and Gettysburg formations, lies beyond several structural anomalies and is not readily correlated to the type New Oxford-Gettysburg area" (Kozur and Weems 2007).

Lucas and Tanner call the biostratigraphic zones of Kozur and Weems "oversplit" and "in need of taxonomic revision" (Lucas and Tanner 2007). They recognize that the lack of a standard biostratigraphic section for the Triassic-Jurassic Boundary forced Kozur and Weems to compare the Newark succession with the incomplete record of Middle Carnian Germany, but they also go on to say that independent correlations would add merit to their argument (Lucas and Tanner 2007). Even though Kozur and Weems provide a clear analysis of their data, there are inherent limitations to their work, given the scarcity of sites and specimens.

Lastly are the plants (Figure 5), which range from the Carnian to the Norian (Cornet 1977). As of right now, the age of the Fulton Site remains enigmatic, though it is most likely that the site is Carnian - Norian in age.

Conclusions/Summary

The Triassic Period, the first period of the Mesozoic Era, was one of extensive geological and biological change. As Pangea began rifting apart, the faunas of the late Paleozoic, early Triassic, and the origin of the later Mesozoic and Cenozoic faunas overlapped in time and space. The Triassic ended with a mass extinction that wiped out the late Paleozoic fauna, and also knocked back some of the early Triassic diversity. The debate continues about the timing and the cause of the extinction. Some think it was a gradual extinction, lasting millions of years, others think that it happened all at once at the latest Triassic, and yet other support a dual-extinction, with some lineages dying out between the Carnian and Norian epochs, and others at the Triassic-Jurassic boundary. Getting an age for the events leading up to the faunal change is critical to understanding this period.

The Newark Supergroup, the name given to the sedimentary and volcanic rocks of the Middle Triassic-Early Jurassic periods, provides the basis to time the events of the Triassic. The supergroup contains the best eastern North American terrestrial fossils of Triassic Age, and is the most continuous rock record for this time. The Fulton site lies within the Newark Supergroup, and most likely along the Carnian - Norian border, though it has yet to be thoroughly stratigraphically correlated.

This study has provided several lines of evidence: lithological and structural that indicate that the site lies within the Gettysburg Formation. Its siltstone deposits and sedimentary structures indicate a lacustrine, rather than fluvial paleoenvironment. The fossils found at and near the site can narrow the age to Carnian through Norian, though it cannot be any more specific until more fossils are discovered.

Suggestions for Future Work

In order for these conclusions to be better supported, one would need to find evidence of the contact closer to the site. No one has completed a thorough inventory of the fauna on the site yet, so the possibility for finding more body or trace fossils is always present. The addition of more fossil content could potentially restrict the age further.

Acknowledgements

I have several people to thank for assisting me with this study. Firstly, my advisors (Tom Holtz, John Merck, Richard Fulton, and Robert Weems), all of which helped me throughout this yearlong project. Secondly, thanks to John and Linda Ballinger for allowing me to conduct this study on their property, and to their dogs, who kept me company while I was there. Thirdly, to my family and Josh Gold, who are constant sources of support and intellectual development. A quick thanks to Paul Olsen (Columbia University), Joe Smoot (U.S. Geological Survey), Thomas Lipka, and Brian Axsmith (University of Southern Alabama), who were all willing to lend a helping hand. Lastly (but not leastly), thank you Susan Drymala for the many times you came with me, and all the pictures you took, thank you Peter Skold for the competition, and thanks to David Tana and Kate Gold for the fun field days.

Appendix 1: Figures

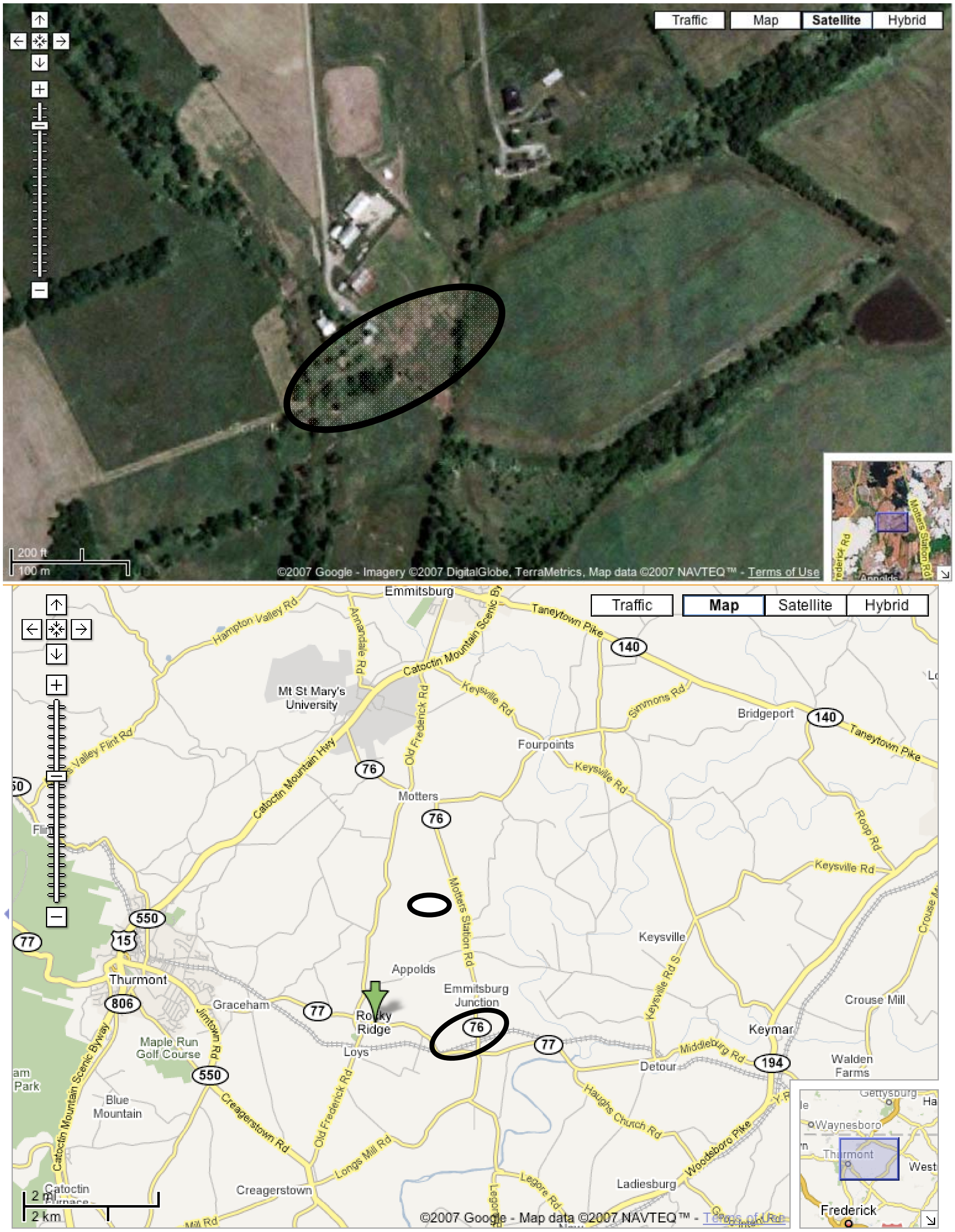


Figure 1: A) Top: Satellite map of the Fulton site. The oval indicates the outcrops. B) Bottom: Map view, smaller oval is the Fulton Site, bigger oval is railroad cut.

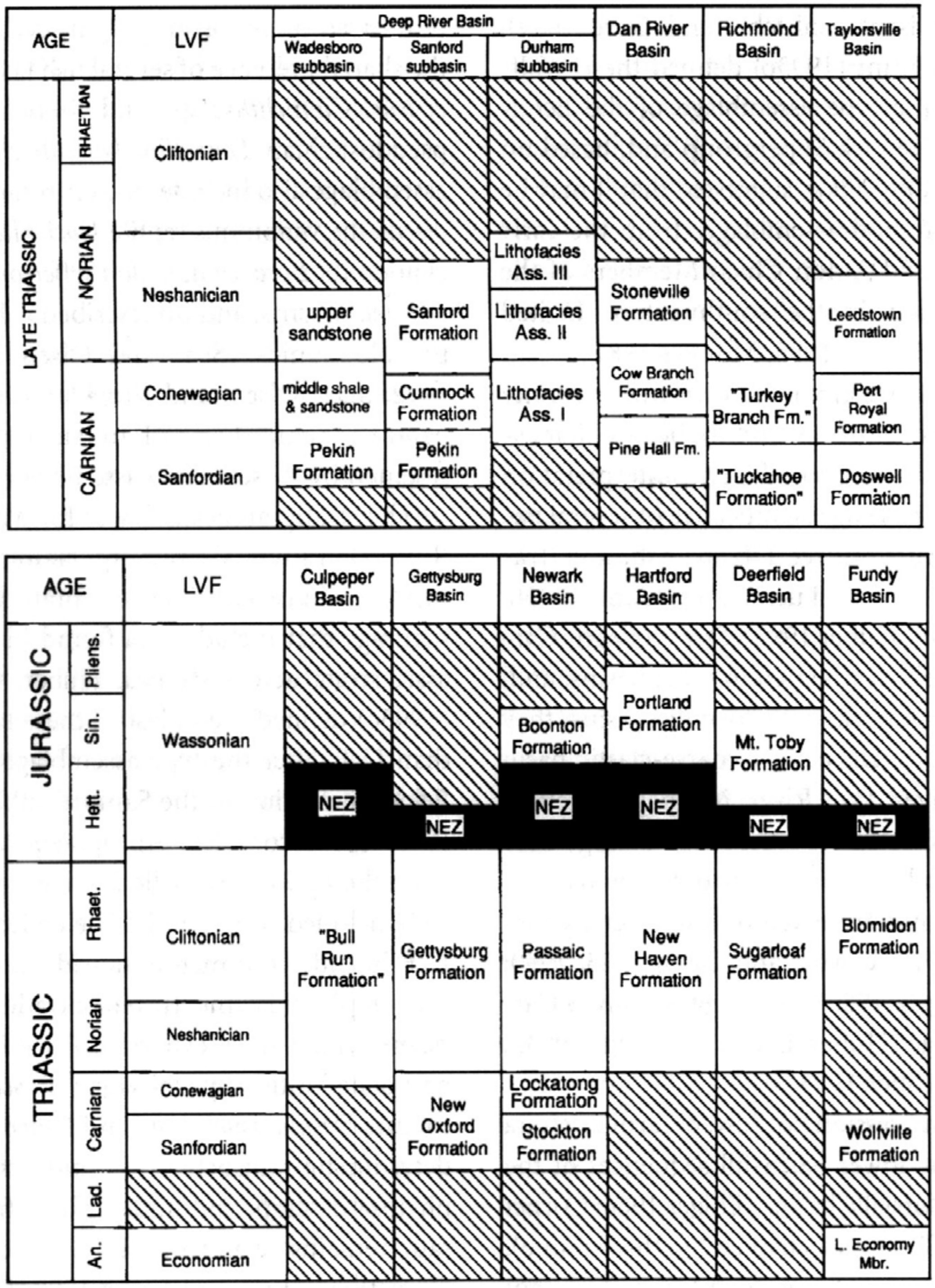


Figure 2: Stratigraphic column of the Newark Supergroup. The Fulton site is in the Gettysburg Basin. Taken from Huber, Lucas, and Hunt (1993).

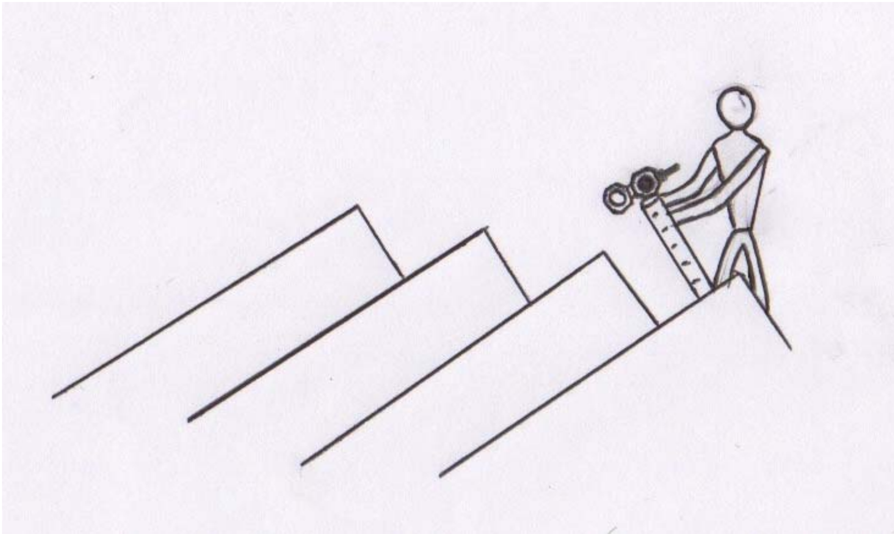


Figure 3: Schematic representation of experimental procedure. Diagram courtesy of Erica Guzman drawn November 17, 2007.

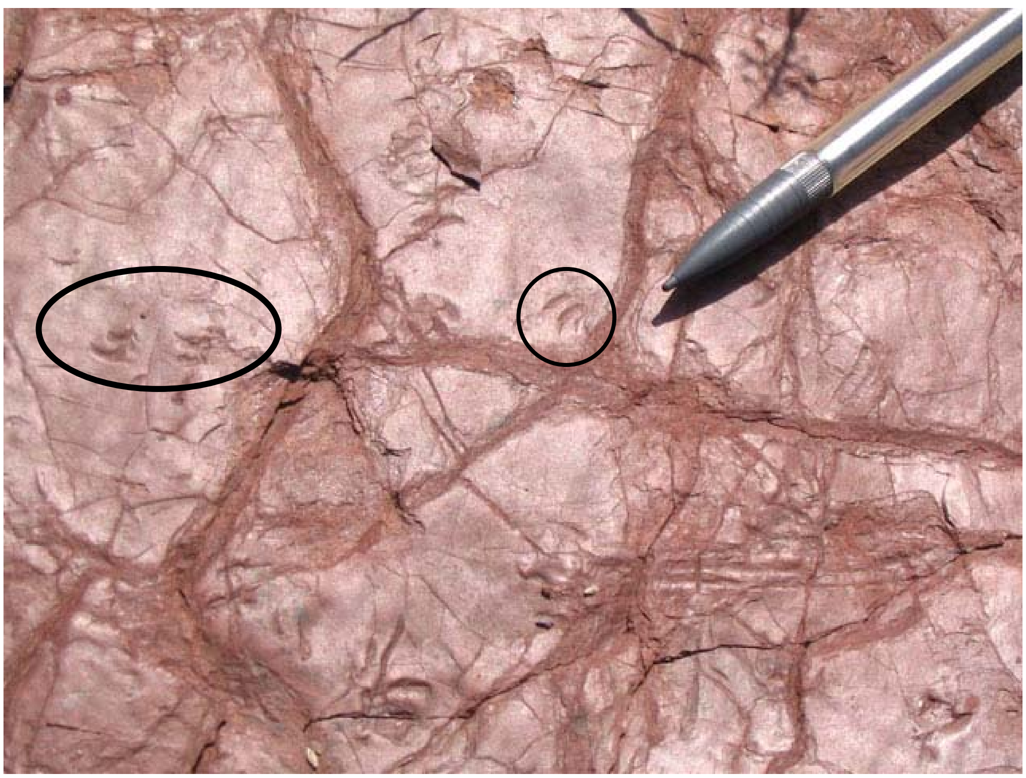
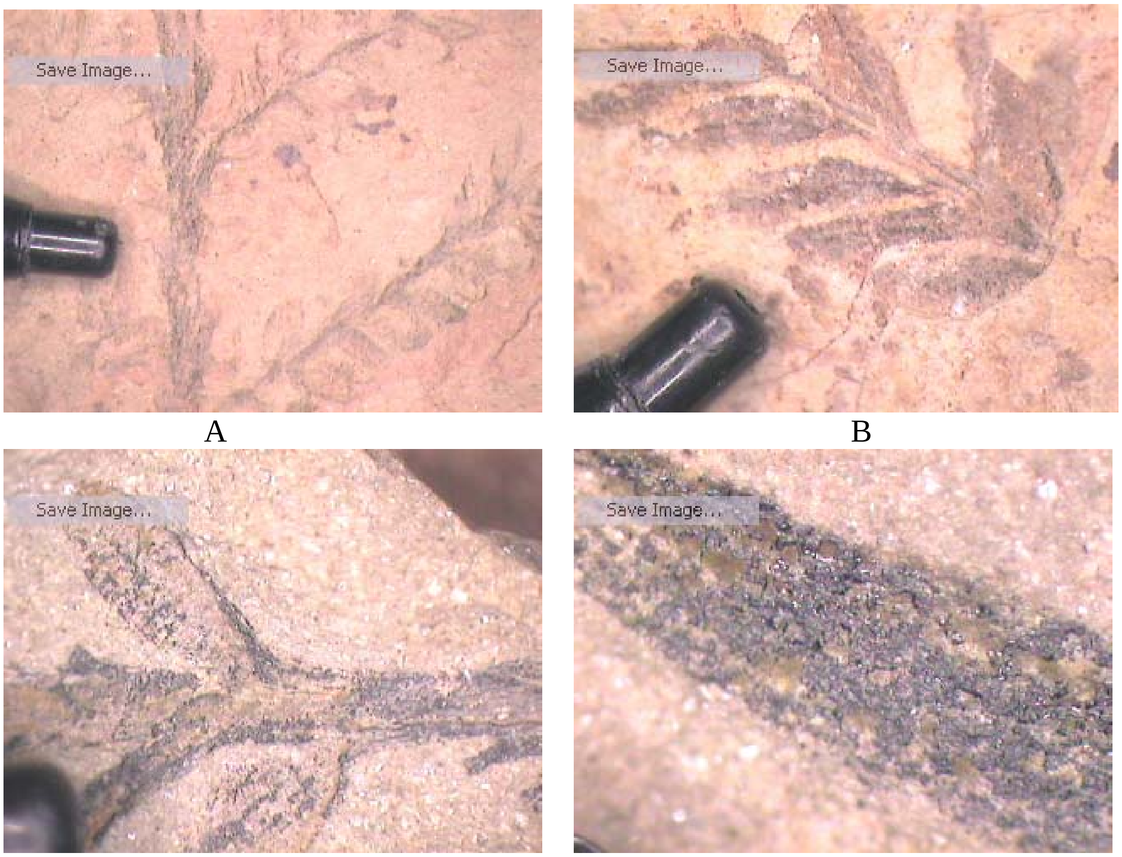


Figure 4: *Gwyneddichnium* trace fossils as seen on the site. Photo taken September 22, 2007.



A B C D

Figure 5: Fossil plant material, identified as *Pagiophyllum diffusum*, from the plant site. A) Branch, B) and C) Close up on fronds, D) Close up on leaf. Photos taken in October 2007.

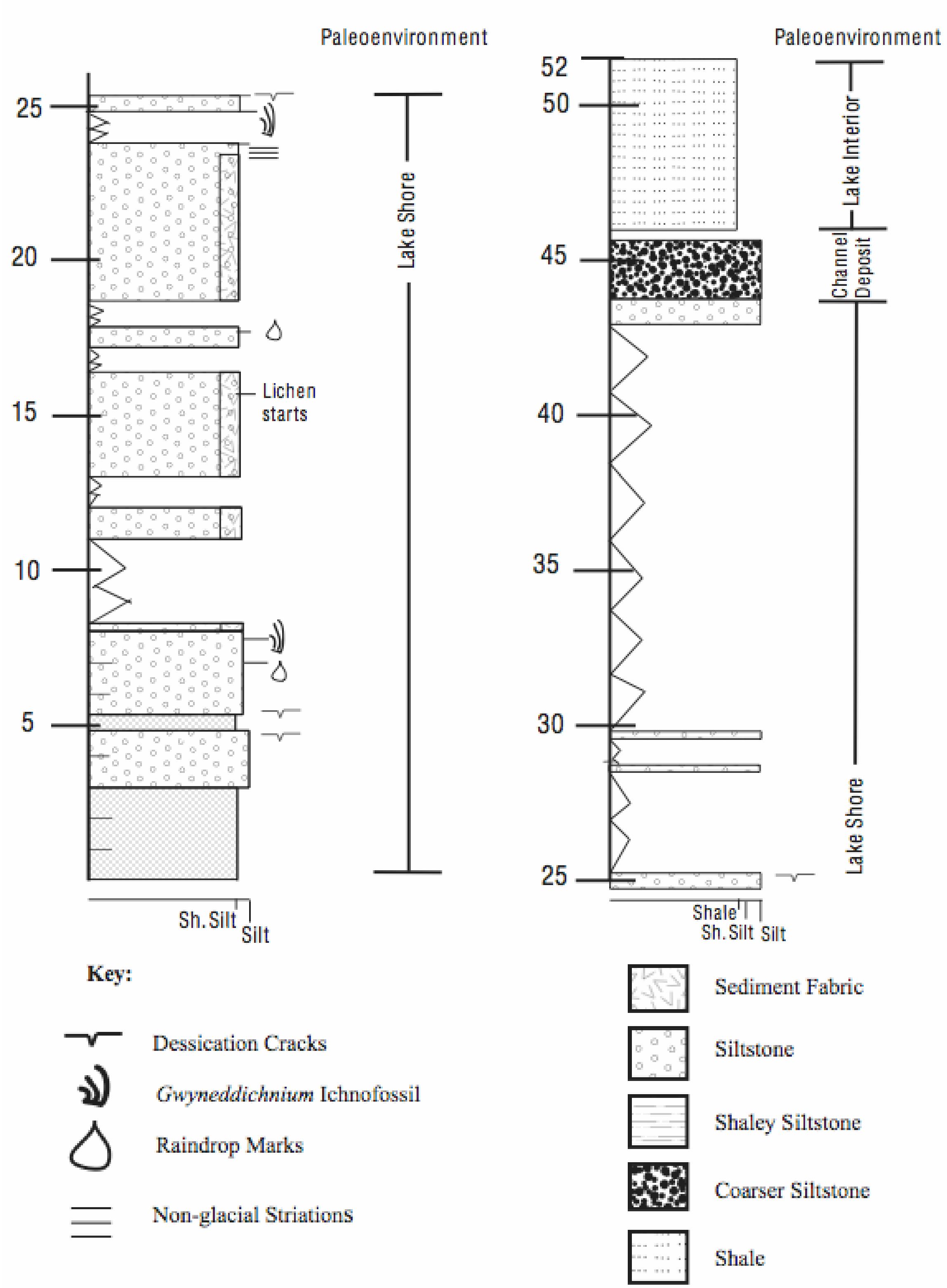


Figure 6: Stratigraphic column of the Fulton site. Error on the meter measurements is ± 4.16 cm.

Appendix 2: Error Calculations

Table 1: Dip Error

	Bed 1	**Bed 2**
Dip measurement	20°	21°
	21°	21°
	17.5°	21°
	18.5°	22.5°
	16.5°	23°
	18°	23°
	20°	22°
	20.5°	23°
	21°	22.5°
	17.5°	21°
Total	190.5°	220°
Mean	*19.05°*	*22°*
Standard deviation	*1.64*	*.91*

Sample calculation:

Standard deviation = square root [∑ (mean – measurement)^2/(n-1)] where n is total measurements

σ = square root [((19.05-20)^2/ 9) + ((19.05-21)^2/ 9) + ((19.05-17.5)^2/ 9) + ((19.05-18.5)^2/ 9) + ((19.05-16.5)^2/ 9) + ((19.05-18)^2/ 9) + ((19.05-20)^2/ 9) + ((19.05-20.5)^2/ 9) + ((19.05-21)^2/ 9) + ((19.05-17.5)^2/ 9)]
σ = square root (2.69) = **1.64**

Table 2: Stratigraphic Error

	Section 1	**Section 2**
Distance from first measurement	4 cm	5 cm
	1.5 cm	12 cm
	0 cm	9 cm
	1 cm	.5 cm
	0 cm	4 cm
	0 cm	1.5 cm
	4.5 cm	11 cm
	5 cm	.5 cm
	0 cm	6.5 cm
	0 cm	7 cm
Total	16	57
Mean	*1.6*	*5.7*
Standard Deviation	*2.07*	*4.16*

Sample calculation:

Standard deviation = square root [∑ (mean – measurement)^2/(n-1)] where n is total measurements

σ = square root [((1.6-4)^2/ 9) + ((1.6-1.5)^2/ 9) + ((1.6-0)^2/ 9) + ((1.6-1)^2/ 9) + ((1.6-0)^2/ 9) + ((1.6-0)^2/ 9) + ((1.6-4.5)^2/ 9) + ((1.6-5)^2/ 9) + ((1.6-0)^2/ 9) + ((1.6-0)^2/ 9)]
σ = square root [4.28] = **2.07**

Appendix 3: Honor Pledge

I pledge on my honor that I have not given or received any unauthorized assistance on this assignment/examination.

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