

Investigation of Keyser Limestone Paleoenvironments at the Cumberland Bone Cave

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Abstract

The Keyser Limestone represents shallow patch reef environments dating from the Late Silurian to the Early Devonian. It is a member of the Helderberg Group, a unit of limestone formations located on the eastern edge of the Appalachian Basin. Multiple shallow marine facies are present in the Keyser Limestone, ranging from tidal flats to open marine shelf. At the Cumberland Bone cave, famous for its Pleistocene Epoch fossils, an outcrop of the Keyser Limestone has not yet been subject to analysis. The objective for the research will be to record the stratigraphy present at the outcrop and compare it to work done previously on the Keyser Limestone. The null hypothesis is that no facies change will be observed, with three special hypotheses: a transgressive sequence is observed, a regressive sequence is observed, or some combination of transgression/regression is observed. Data to be obtained with field work will be measurements of bed thickness and descriptions of lithology. Measurements were done with a measuring tape and Jacob's Staff. The total thickness of the section is 60.72 ± 0.02 meters, with six major changes in lithology observed. These changes in lithology translate into three major changes in facies. The facies changes with from an open marine shelf, to a regressing marine shelf, to a lagoon facies. This shows a transgression at the base of the section changing to a regression, agreeing with special hypothesis #3. Possible future work could include finding local contacts, and explaining the presence of crinoids throughout the entire section.

Introduction

According to Dorobeck and Reed (1986), the Helderberg Group is a lithostratigraphic unit present in the east edge of the Appalachian Basin. Its age ranges from the Late Silurian to the Early Devonian in age. The sediments that make up the Helderberg Group rocks are all limestones. Four separate formations in this group are present in the central Appalachians: the Keyser Limestone, New Creek Limestone, Corriganville Limestone, and Licking Creek Limestone (ordered youngest to oldest). The formation lying above the Helderberg Group is the Oriskany Sandstone.

The Keyser Limestone is the oldest formation present in the Helderberg Group of the central Appalachians. It is fairly thin, reaching up to 85 meters in some locations. The age for this formation ranges from the Late Silurian to the very Early Devonian (Dorobek and Reed 1986). Limestone deposition within the formation represents shallow marine environments, including some patch reefs.

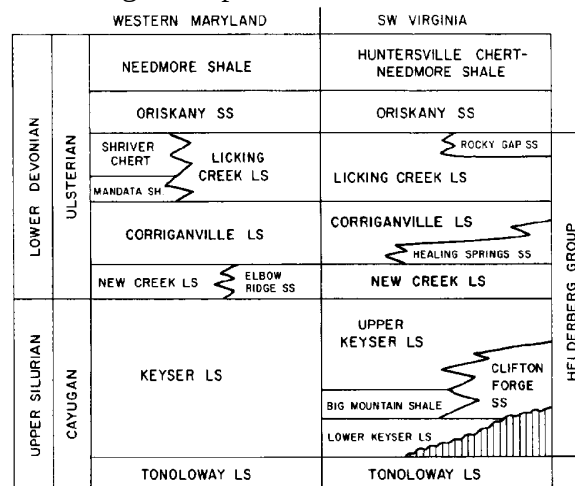


FIG. 4.—Regional stratigraphic correlation chart, Helderberg Group, central Appalachians.

Figure 1. A generalization of the stratigraphic location of the Keyser Limestone (Dorobeck 1986)

Following Makurath (1977), there are four distinct depositional environments represented in the Keyser Limestone. The differences are distinguished by their lithologies, sedimentary structures, and fossil content (Table 1). Closest inland are the tidal flat environments. These are micritic limestones with some intraclasts present where channels formed. Beds are thin and exhibit many sedimentary structures: mudcracks, bioturbation, ripple cross-laminations. Fossil content here is low, showing some stromatoporoids, ostracods, and algal laminations.

Moving away from the shore is the next depositional environment, lagoons. Beds here are thin, showing laminations. The rock is micritic and massive. Sedimentary structures present are burrows, but the rock is usually bioturbated so any structures are rare. Common fossils in this rock are brachiopods, bryozoans, corals, and a high abundance of stromatoporoids.

Following the lagoons are the barrier island complexes. These are thick, lenticular beds of quartz arenites and some biomicrites. Cross beds and ripple marks are the present sedimentary structures. Crinoids, bryozoans, and brachiopods make up the common fossil fauna.

The deepest depositional environment present is the open marine shelf. These rocks are composed of argillaceous calcarenites. Bedding here is thin again. Sedimentary structures present are oscillation ripples, graded beds, turbidites, and storm surge deposits. Fossil fauna becomes very diverse here, and all previously mentioned organisms are present along with gastropods, tentaculitids, and trilobites (Makurath 1977).

The outcrop of Keyser Limestone to be studied for this project is located in western Maryland. A railroad was cut through a section of the Keyser Limestone, exposing a cave. The cave is famous as the Cumberland Bone Cave for its Pleistocene Epoch fossils found within (Norden 2006). A structural feature, the Wills Mountain Anticline, contains these rocks. The Cumberland Bone Cave is located on its western flank (Clark et. al. 1913). The orientation of the beds is approximately N55°E. The dip varies based on where you are in the fold. The thickness of the outcrop is approximated at 118 meters, by taking paces and measuring the pace length.

	Tidal Flat	Lagoon	Barrier	Shelf
Ostracoda	X	X	X	X
Trilobita				X
Tentaculitida	X			X
Stromatoporoidea	X	X	X	X
Gastropoda	X	X		X
Rugosa		X	X	
Bryozoa		X	X	X
Crinoidea			X	X
Cystoidea			X	X
Brachiopoda		X	X	X

Table 1. A summary of common fossil fauna present within the Keyser Limestone (Makurath 1977).

Objectives of Research

Studying the geological record allows us to reconstruct the environmental history of the past. Geologists can take the data, and construct paleoenvironments. In the present there is a limited amount of time that we have had to observe change. By looking to the past, there are hundreds of millions of years in which to observe how our world may change into the future. It can be observed how environmental changes affected life. These observations can be related to present-day changes, helping us better understand these changes.

The Keyser Limestone is composed of multiple paleoenvironments. Past work has been done on the Keyser Limestone at outcrops as far south as Virginia going up north into Pennsylvania. No work has been done to analyze the outcrop at the location containing the Cumberland Bone Cave. My project will involve an initial analysis of the stratigraphy, placing my site into a sequence of paleoenvironments.

After comparing the stratigraphy of the outcrop to certain paleoenvironments, the outcrop can be compared to previous work done on other exposures of the Keyser Limestone. This will enhance the overall knowledge of the formation. It is possible that new information regarding the Keyser Limestone could be found when looking at the stratigraphy. Beyond identifying the paleoenvironments, knowing the stratigraphic

sequence at this outcrop may allow it to be given an approximate date of formation. This would be done by matching the sequences seen to those already observed in the Keyser Limestone and the Helderberg Group as a whole.

I examined whether or not the shoreline moved over the period of deposition. The hypothesis is split into three special hypotheses:

Null Hypothesis – No particular facies change is present at this site

Special Hypothesis 1 - A transgressive sequence is represented at this site

Special Hypothesis 2 - A regressive sequence is represented at this site

Special Hypothesis 3 – A series of transgressive/regressive cycles are represented at this site

Methods

There were two sets of data taken in this project: Bed thickness and lithology of the rock at each bed. The data was taken entirely in the field, with samples of rock taken at each major lithology change noted in the outcrop. To reach the field site, I drove to LaVale, MD where the outcrop lies exposed on the Great Allegheny Trail (Appendix 2). The distance to the outcrop from parking is approximately 1.4 miles when measured using Google Earth. Samples were transported back to the car in labeled bags.

Two different techniques were used for measuring bed thickness. When first measuring the section, a tape measure was used. The outcrop had been cut through for a railroad, so the beds are exposed nearly perpendicular to their bedding plane. The bed thicknesses can be measured with the tape positioned perpendicular to the upper and lower bedding planes. The measurements were taken in centimeters. This is a measured value, so error needs to be found. To estimate the uncertainty, multiple measurements were taken on select beds and used to calculate a standard deviation. The standard deviation at each of these beds was then averaged to obtain an estimate of the error for bed thickness. Another centimeter of error was added after to account for the non-perpendicularity.

At localities at and below the Cumberland Bone Cave, beds were not as easily apparent. To measure the remaining section, a 48-inch Jacob's Staff was used. Measurements were later converted to centimeters for consistency. To use the Staff, strike and dip was taken at the first bed. The Staff was placed on that bottom surface and tipped 90 degrees from the strike in the direction of the dip. The amount the Staff was dipped equaled the dip of the bedding, measured by a compass resting at the top of the staff. When the Staff is at the right dip, I sighted through the compass on top to a point on the ground where I would place the bottom of the staff. This represented 48 inches of section each time the Staff base is moved.

Error for the Jacob's Staff was taken measuring the same spot repeatedly in the field. The distance along the ground was measured from the first position of the base of the Staff to the second position. Using trigonometry, the actual measured thickness of the section by using the Staff was calculated. The standard deviation of this calculated thickness was taken as the error for the Jacob's Staff.

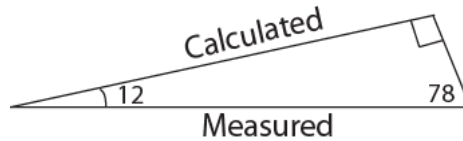


Figure 2. The method used to find Jacob's Staff error shown visually

Beds with the same characteristics were be grouped into members. Characteristics used to group the beds were lithology and fossil content. These characteristics were be observed roughly in the field and taken back as samples where they were more closely analyzed. Samples were taken at the lowest in section observed lithology change. At this location, the distance down the bed is noted and a sample of rock is taken from the outcrop.

Rock samples were described with three variables: rock type, types of fossils present, and percent abundance of fossils. The rock type of each sample was classified by using both the Folk and Dunham methods (Folk 1959 and Dunham 1962). For the Folk method, grain size and matrix composition are estimated. The Dunham method summarizes the depositional texture. Sedimentary structures will be noted, such as zones of decreased sedimentation within each sample. Fossil content will be compiled based on observations both in the rock sample taken, and in the section of the outcrop where the sample was removed. Using catalogs of fossils found within the Helderberg Group (Maryland Geologic Survey 1913), fossils in the rock will be defined by their species.

A measured section was produced from the data and observations. The measured section shows the relative bed thickness along with the lithology. Lithology data represented will be rock type, matrix composition, and grain size. The fossil assemblage in the limestone was also be noted and displayed on the measured section.

Lithology, along with fossil assemblage, noted in the measured section will be used to identify a depositional environment. To do this, I compared what I found at my site with data previously collected on depositional environments (Figure 1). Papers done at other sections of the Keyser Limestone were the primary source of information. These papers helped me correlate my data with previously measured sections of the Keyser Limestone.

← Onshore Offshore →				
				MHW MLW
Depositional environment	Supratidal; intertidal; shallow subtidal ponds	shallow subtidal lagoon	tidal inlet; offshore bar; mud shoals	open shelf during regressive phase; barriers absent
Rock type	micrite & pelmicrite on flats; intraclasts in channels	nodular pelmicrites; peloidal calcarenites; stromatopora; coral biomicrites (biostromes)	quartz arenites; calcarenites; minor biomicrites (boundstone)	argillaceous calcarenite
Bedding	supratidal; laminae intertidal; thin subtidal; massive	calcarenites: thin often current laminated & ripple cross-laminated micrites: massive, usually bioturbated	thin to thick; often lenticular	thin
Sedimentary structures	mudcracks; sheetcracks; "birdseye" structures; bioturbation; ripple cross-laminae; algal laminae; graded thin beds & laminae	burrows; current laminae small scale cross-laminae	quartz arenites: bimodally oriented trough cross-beds & washed out ripples calcarenites: planar cross-beds reactivation surfaces abundant	oscillation ripples; graded beds; shallow water turbidites & storm surge sand deposits
Fossil diversity	low; locally abundant low relief domal stromatopora; ostracodes	moderate; brachiopods, bryozoans, corals & stromatopora; locally abundant	moderate; crinoids, bryozoans, robust brachiopods; fossils often broken & abraded	low to moderate
				high in carbonate interbeds; cystoids, crinoids, bryozoans, brachiopods; frequent in situ preservation

Figure 3. Lithology table constructed in a paper in depositional environments of the Keyser Limestone (Makurath, 1977)

Noting changes in depositional environments gave an indication for whether a transgressive or regressive sequence is observed. As you move forward in time, if the environments become shallower, a regressive sequence is observed. If the environments become deeper, a transgressive sequence is observed.

Results

Uncertainty measurements using the measuring tape came from the first five beds observed. The last five beds used varied in their thicknesses, so all were used to find a range of standard deviations. The average standard deviation was 1.5 cm, while the minimum and maximum respectively are 0.91 cm and 2.2 cm. Uncertainty in the Jacob's Staff measurements was small, with a standard deviation of 0.93 cm. The accuracy of the Staff was off though, with the calculated thicknesses averaging 3.31 cm less than actual length of the Staff. This anomaly in thickness could be explained by the ground being a small incline which was not taken into account.

The brachial valves of brachiopods found throughout the section were used as a geopedal structure: brachial valves' convex face lay upwards when the brachiopod is at rest in sediment. In non-bioturbated sediment, these brachial valves will remain facing upwards in death. Beds abundant in brachiopods indicated that the up-direction is to the southwest. The up-direction also confirms the presence of this outcrop as part of the Will's Mountain Anticline.



Figure 4. Brachiopods used as a geopedal structure, the highlighted semicircles are brachial valves, with the convex side pointing up.

The total thickness of the section is 60.72 ± 0.02 meters. Six changes in the lithology are observed. Thicknesses of these lithologies vary, ranging from 2.95 ± 0.02 to 24.12 ± 0.02 meters. This thickness falls within the thickness of the Keyser Limestone as measured at other localities. The thickest section of Keyser Limestone is at the type locality in Keyser, Virginia. The recorded thicknesses diminish moving north towards Pennsylvania where outcrops are recorded at 35 meters and then pinches out. The strike of bedding is N50W. Dip varies vertically due to the presence of a local-scale anticline structure.

Lithologies

Lithology	Thickness (m)	Approximate Percent Fossils	Fossil Content
6	4.62	5-10%	Bryozoans, Crinoids, Brachiopods
5	7.56	5-10%	Bryozoans, Brachiopods, Bivalves
4	2.95	5-10% with brachiopods, 70-80% with stromatoporoids	Brachiopods, Stromatoporoids
3	24.12	30-50%	Bryozoans, Crinoids, Brachiopods, Tentaculitids
2	13.41	30-50%, decreasing upwards	Bryozoans, Crinoids, Brachiopods, Trilobites (<i>Dalimites</i>)
1	8.06	50-60%	Bryozoans, Crinoids, Brachiopods

Table 2. Brief summary of data taken from rock samples at the base of new lithologies

Lithology 1

The base of the outcrop is a thinly bedded micritic limestone. The section is 8.06 ± 0.01 meters thick. Beds are densely populated with crinoids, brachiopods, and bryozoans. Percent content in these fossils are approximately 50-60%. Using the Folk classification scheme, the first lithology is a packed biomicrite (>50% fossils, micrite matrix). Dunham classification places the rock as a wackestone (>10% fossils, mud supported). The beds are not disturbed. Discovery of an intact crinoid arm with pinnules attached indicates relatively good preservation. Fossils found in these beds are articulated.

Lithology 2

The lithology is an alternating series of thick (5-15 cm) beds and thin (<1 cm) beds. Thickness of this section is 13.41 ± 0.01 meters. Samples from each type of bedding fall within the same classification. Percent fossil abundance ranges from 30-50%, with lower abundances farther up section. This unit includes sparse biomicrites and wackestones, as identified by their percent fossil abundances and micrite matrix. Fossil content in this rock includes crinoids, brachiopods, bryozoans, and trilobites. Disarticulated fossils begin to appear here alongside articulated versions. Trilobites of the *Dalimites* genus were rare and found only in the thinly-bedded sections.

Lithology 3

Above the thin-thick alternate bedded sparse biomicrite (10-50% fossils, micrite matrix), is the weathered section containing the Cumberland Bone Cave. This section is thick-bedded, and 24.12 ± 0.01 meters thick total. The rock is classified as either a sparse biomicrite or a wackestone. Abundant fossils at this location are bryozoans. They vary in their abundances but compose up to 50% of the rock towards the top of this section of the Keyser Limestone. Other fossils include crinoids, brachiopods, and tentaculitids.

Lithology 4

The next observed lithology change is layers of stromatoporoid-rich limestone. The thickness of this section is 2.95 ± 0.02 meters. This is made up of three prominent beds. The two beds on top and bottom are composed heavily of stromatoporoids and brachiopods. Percent abundance of stromatoporoids in their beds reaches 70-80%. The central bed is composed of brachiopods, which were used as the geopedal structure. Using folk classification, this is a fossiliferous biomicrite (1-10% fossils, micrite matrix) in the brachiopod-bearing beds and a packed biomicrite where stromatoporoids are present. And using Dunham classification, the stromatoporoid beds are a wackestone and the brachiopod bed is a mudstone (<10% fossils, mud supported).

Lithology 5

The next rock transitions back to a fossiliferous biomicrite/mudstone. This portion is 7.56 ± 0.02 meters thick. Alternating light and dark bedding suggests the possible presence of algal mats. Other fossils present include brachiopods, bivalves, and bryozoans. Beginning with this lithology, fossil abundance decreases going upward.

Lithology 6

The section is topped off by a thick-to-thin bedded fossiliferous biomicrite/mudstone. The thin beds are much more abundant in fossils, and could be classified as a sparse biomicrite/wackestone. Fossils present in this section are bryozoans, brachiopods, and crinoids. Crinoids and bryozoans in these limestones are disarticulated, appearing as broken parts and individual rings of a crinoid stem. These fossils appear in both types of beds, only varying in abundance. This top section is 6.62 ± 0.02 meters thick.

Lithology	Thickness (m)	Folk Classification	Dunham Classification
6	4.62	Fossiliferous Biomicrite	Mudstone
5	7.56	Fossiliferous to Packed Biomicrite	Mudstone
4	2.95	Sparse Biomicrite	Wackestone
3	24.12	Sparse Biomicrite	Wackestone
2	13.41	Sparse Biomicrite	Wackestone
1	8.06	Packed Biomicrite	Wackestone

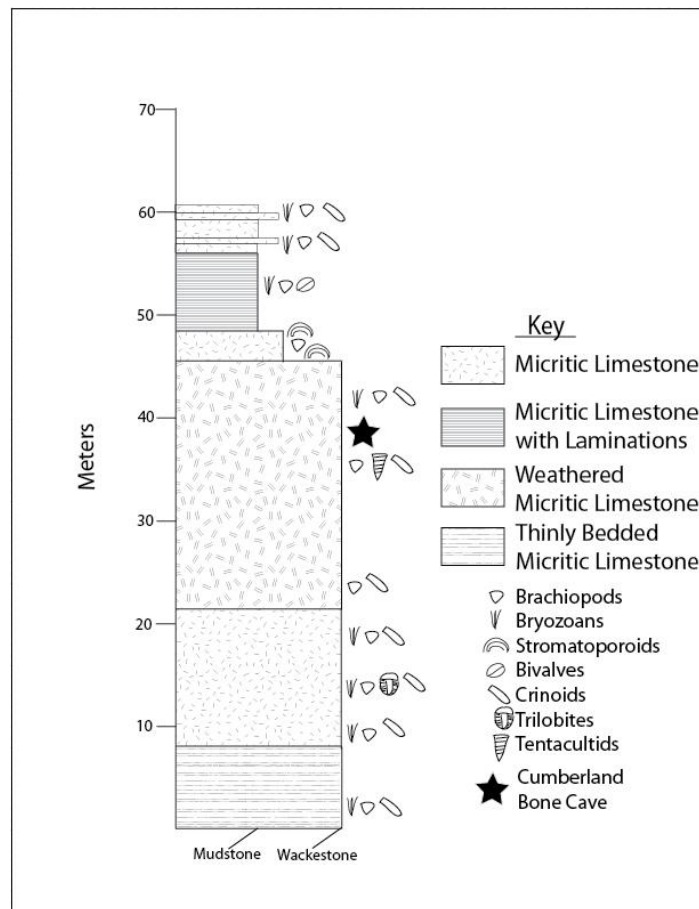


Figure 4. Measured section for the Keyser Limestone at the Cumberland Bone Cave

Interpretation of the Data

The base of the section matches the characteristics of a shaly carbonate lithofacies (Makurath 1977). The environment this would represent is a shallow open marine shelf. Characteristics of these beds agree with those previously identified by a paper summarizing all currently recognized lithofacies in the Keyser Limestone (Makurath 1977). The identifying characteristics are the bed thicknesses, a large fossil assemblage, and strong preservation of the fossils. Thin, shaly beds match up with previous observations of Keyser Limestone open shelf lithofacies. Fossil content and preservation tells us that these deposits were likely done during a transgression. The strong preservation of fossils shows that the shelf was very low-energy and little disturbed the sediment.

The next two lithologies agree with a regressing open marine shelf (Makurath 1977). Individual bed thicknesses and fossil assemblage remains consistent with the open shelf established at the base of the section. Moving up section, the quality of fossil preservation and percent fossil abundance drops. The overall abundance in fossils begins to drop immediately after the first identified lithology. As well, I no longer found many

intact fossils, and most were identified as parts. Makurath, in his 1977 paper, states that this indicated more violent activity on the shoreline prograded.

Walther's law states that any facies that would accumulate next to another facies will also appear directly above or below that facies in vertical sequence. This would mean that the next lithology to appear would be a calcarenite lithofacies representing a barrier island complex. This identified facies does not appear in the section at the Cumberland Bone Cave. This manages to agree with previous observations of regressing Keyser Limestone sequences. The barrier island facies is absent during regression in all cases.

The final three lithologies can be attributed to the same environment. The characteristics of these agree with previous observations of a lagoon facies or other very shallow subtidal facies. Above the regressing open shelf deposits are the stromatoporoid-rich biostromes. Previous descriptions show these have thick bedding (0.5 to 2 meters), a micrite matrix, and upwards of 75% stromatoporoid composition. The biostromes are believed to be subtidal channel deposits (Makurath 1977). The brachiopod-bearing bed in between matches up with the nodular limestone lithofacies.

The top two lithologies can both be described as a nodular limestone lithofacies, which matches up with a lagoon environment. Fossil content of blue-green algae is lost in the final lithology. The uppermost lithology is also interbedded with what can be identified as peloidal calcarenites. These are thin-bedded, micrite dominated, moderate fossil diversity deposits. They are also commonly found interbedded with nodular limestones at the top of other Keyser Limestone outcrops found north of the Keyser, Virginia locality.

While the lithology of the upper layers agree with previous studies done on the Keyser Limestone, fossil content does not quite match up. Crinoids are found throughout the entire section with similar frequency to brachiopods. In past papers (Makurath 1977, Dorobek and Reed 1986, Barwis and Makurath 1978), crinoids had been found only in barrier island and open marine shelf facies. The lithology says convincingly that there likely was a lagoon facies here during deposition, but with crinoids. Because the crinoids appear in disarticulation. It may have been that they only exist in these environments as sediment and not life.

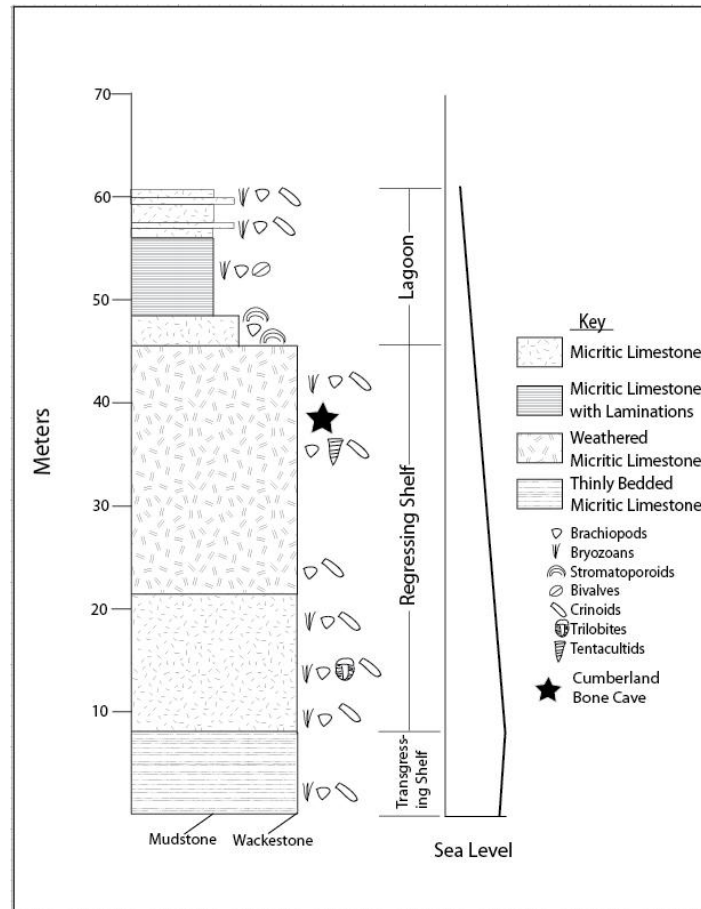


Figure 5. Measured section of the Keyser Limestone at the Cumberland Bone Cave, showing the interpreted changes in sea level.

Conclusions

The observations match up with Special Hypothesis #3, that a series of transgressive and regressive sequences are observed. Specifically, the base shows the end of one transgression and moves to a regression through the rest of the section. Ordering of lithofacies here agrees with that of other nearby outcrops, but is somewhat thinner. No recognizable contacts were observed above or below the section due to the extensive weathering at the site. More section could have been lost because of that weathering.

Future work from this could be to find contacts above or below by surveying the area around the Cumberland Bone Cave, which I did not have time to do. As well, a study of the crinoids in the Keyser Limestone may lead to some interesting observations after finding them through the entirety of the section, disagreeing with other studies done on the Keyser Limestone.

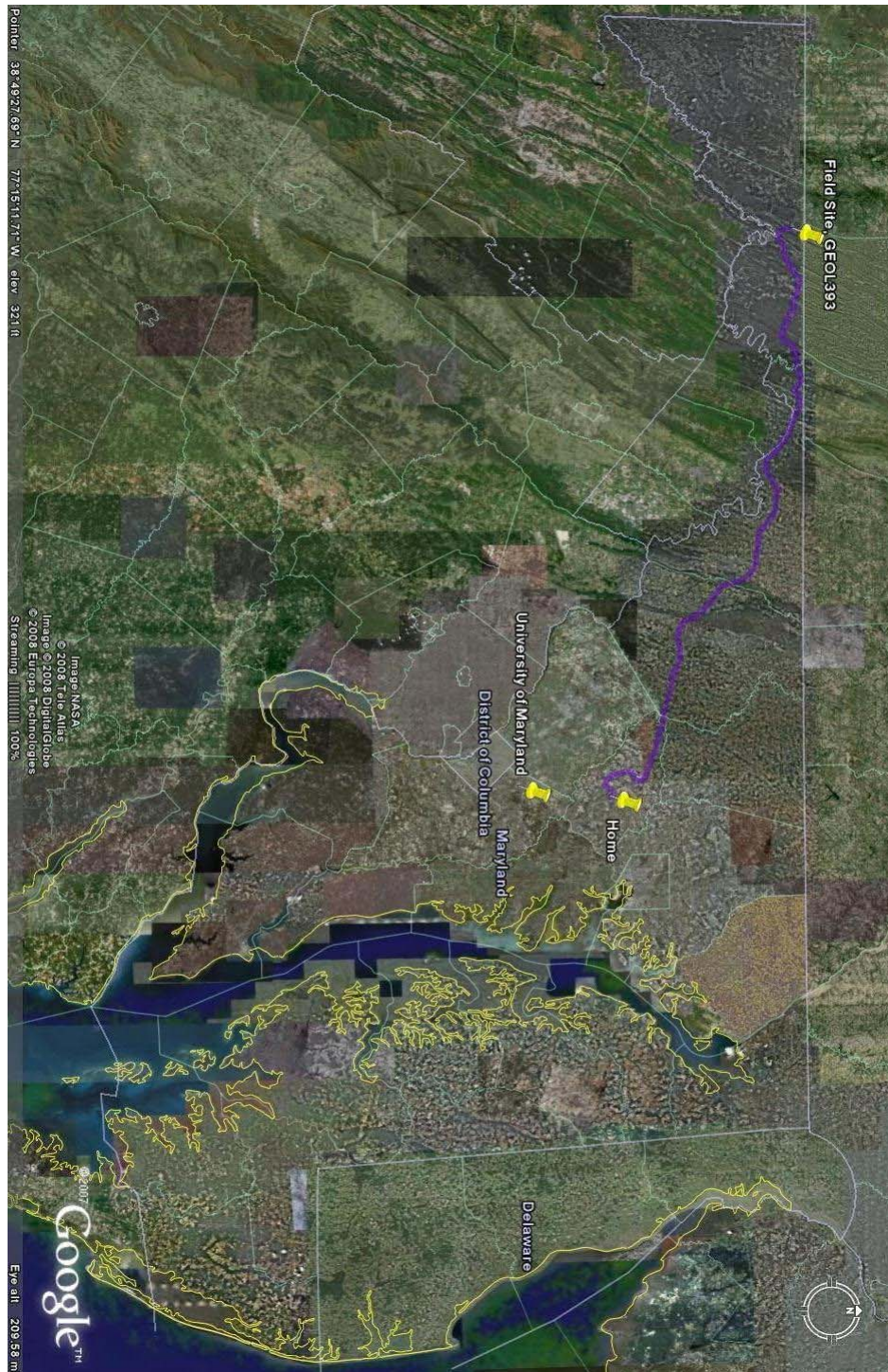
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Appendix 1: Honor Statement

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

Appendix 2: Location of the Field Site



The image is taken using Google Earth. The three pins label important locations: The field site, and the two locations I left from to reach the site: The University of Maryland Campus and my home in Columbia, MD. The purple line on the map represents the driving directions I used to reach the site. The Field Site is located in La Vale, MD on the Great Allegheny Trail.

Appendix 3: Error Calculations

Measuring Tape:

	Bed 1	Bed 2	Bed 3	Bed 4	Bed 5
Measurement 1 (cm)	53.5	29.4	10.7	32.0	13.7
2	53.0	28.2	11.1	35.9	19.0
3	53.1	28.3	8.2	29.0	19.0
4	53.6	26.0	7.0	33.4	12.5
5	55.0	27.7	10.0	34.2	16.0
6	52.9	27.0	9.6	32.3	14.4
7	55.5	27.7	9.5	33.8	17.2
8	53.1	27.0	10.1	32.0	15.0
9	53.2	26.9	7.9	34.0	13.8
10	53.0	27.4	9.5	31.5	15.3
Average	53.6	27.6	9.4	32.8	15.6
Standard Deviation	0.91	0.94	1.29	1.89	2.22
Average	1.45				

Jacob's Staff:

Measurement (inches)	Measurement (cm)	Dip angle	calculated thickness
55.5	140.97	78	118.96
54.375	138.11	78	116.55
55.625	141.29	78	119.23
55.5	140.97	78	118.96
55.75	141.61	78	119.49
55.75	141.61	78	119.49
55.125	140.02	78	118.15
55.625	141.29	78	119.23
55.375	140.65	78	118.69
54.75	139.07	78	117.35
		AVG:	118.61
		STDEV:	0.93
	Jacob staff actual:	121.92	

Appendix 4: Bed Thicknesses

Jacob's Staff Measurements:

Lithology	Full Staff Intervals	Partial Staff Distance	Total Distance (inches)	Total Thickness (meters)
1	6.00	29.25 inches	317.25	8.06 ± 0.01
2	11.00	0 Inches	528.00	13.41 ± 0.01
3	19.00	37.5 Inches	949.50	24.12 ± 0.01

Measuring Tape Measurements:

Measurements were taken between two clear bed surfaces

Lithology 4:

Measurement (cm):
53.7
46.4
61
134

Total: 295 cm = 2.95 ± 0.02 m

Lithology 5:

Measurement (cm):
29.2
32.1
61
49.5
50.2
13.7
32.4
30.5
123.5
71.8
78.7
82.6
16.2
51.8
33

Total: 756.1 cm = 7.56 ± 0.02 m

Lithology 6:

Measurement (cm):
121.5
46.4
52.7
14
59.1
42.5
67
59.1

Total: 462.3 cm = 4.62 ± 0.02 m