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A Faunal Composition of the Late Cretaceous Blue Springs Site in Northeastern Mississippi and Evidence for Potential Paleoenvironmental Differences Between Beds

Ginger Trochesset
University of Southern Mississippi

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A Faunal Composition of the Late Cretaceous Blue Springs Site in Northeastern Mississippi and Evidence for Potential Paleoenvironmental Differences Between Beds

by

Ginger Trochesset

A Thesis
Submitted to the Honors College of
The University of Southern Mississippi
in Partial Fulfillment
of Honors Requirements

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Approved by:

Alyson A. Brink, Ph.D., Thesis Advisor,
School of Biological, Environmental and Earth
Sciences

Jake Schaefer, Ph.D., Director,
School of Biological, Environmental and Earth
Sciences

Sabine Heinhorst, Ph.D., Dean
Honors College

ABSTRACT

The Maastrichtian-age Blue Springs locality of the Coon Creek Member of the Ripley Formation is known for abundant, well-preserved marine fossils, including many genera of microfossils, bivalves, gastropods, decapods, cephalopods, actinopterygians, and other vertebrate organisms. This research contributes to the understanding of the paleontology of the site, as well as the changing paleoenvironmental conditions of the beds throughout deposition.

This project analyzed bulk material collected in 2021 from three fossiliferous beds at Blue Springs: the Lower *Corbula* Bed (Bed C), the Pebble Bed (Bed G), and the *Exogyra-Pycnodonte* Bed (Bed J). Unconsolidated material from Beds C and J was processed through wet sieving, and the resulting Bed J concentrate was picked for fossils under a microscope. The fossils were separated, identified, labeled, and imaged to provide a better understanding of the fossil faunal assemblage of Bed J, which was then compared to fossil material from the other beds to determine paleoenvironmental differences. Finally, the observed fossils from each bed were compiled with records from peer-reviewed articles to produce a fossil faunal composition list of all invertebrate and vertebrate fossil occurrences at the Blue Springs site (Appendix A). Such a list has not yet been published in the geologic literature, and it will be useful for professional researchers and amateur collectors interested in the paleontology of Blue Springs.

The results of this study, specifically the microfossil data, support that Bed J at the Blue Springs site was deposited in a shallow marine, near shore environment with normal salinities and moderate temperatures. The paleoenvironmental conditions of the site as a whole made it a survivable environment that supported over 140 taxa 71 million

years ago, but further analysis of bulk material is necessary to determine what paleoenvironmental conditions are represented by the faunal assemblages of each bed.

Keywords: Blue Springs, Ripley Formation, Paleoenvironment, Maastrichtian, Cretaceous

DEDICATION

This thesis is dedicated to my friend and classmate Robert Brent, who passed away in May 2021 at the end of our junior year at the University of Southern Mississippi. Rob and I met in the fall of 2018 as freshmen in the Honors Colloquium course taught by my thesis advisor Dr. Alyson Brink. Our self-proclaimed “Team Triceratops” took an active learning trip to the Coon Creek Science Center in Tennessee, and we stopped in Blue Springs, MS on our way back to Hattiesburg. As freshmen in majors far removed from geology and paleontology, Rob and I (and our classmate Malik Williams) collected the “pretty things” – *Exogyra costata* valves – in what I now know to be the *Exogyra-Pycnodonte* bed of the Blue Springs site. This course was my first exposure to paleontology, and it is the reason that I changed my major to geology as a sophomore and why I would like to continue my studies in paleontology.

Rob was an integral part of my experience in Dr. Brink’s Colloquium course; he always had a positive attitude and brought something interesting to our class discussions. I will always think of him when studying the Blue Springs site and reflecting on my journey to geology. Rob was consistently friendly, caring, and fun, and he had the best laugh that could brighten anyone’s day. Team Triceratops misses him dearly, but we will carry him in our hearts forever and strive to live out his legacy of kindness. This one is for you, Rob!



Rob at the Coon Creek Science Center in Tennessee, October, 2018.

ACKNOWLEDGMENTS

I would like to express my gratitude to the numerous individuals who made this undergraduate honors thesis possible. First and foremost, I would like to thank my thesis advisor Dr. Alyson Brink. Dr. Brink offered continuous support when I became frustrated or overwhelmed, new approaches and advice to navigate trial and error, abundant resources for specimen preparation and identification, and encouragement in all aspects along the way. She taught me invaluable skills in geological and paleontological research and scientific writing, and she is an excellent mentor, creating pathways for women in science with confidence and enthusiasm. I am grateful for the support she provided me throughout my undergraduate experience as not only my thesis advisor, but also my academic advisor, professor, and mentor.

My bulk sample collection from the Blue Springs site in October 2021 would not have been possible without the assistance of Dr. Brink (Assistant Professor, The University of Southern Mississippi), Mr. George Phillips (State Paleontologist, Mississippi Museum of Natural Science), and Blake Runnels and Tyra Swan (undergraduate student volunteers, The University of Southern Mississippi). Dr. Brink, Blake, and Tyra sacrificed their fall break from college to help, and Mr. Phillips volunteered his time away from the museum to provide guidance. I would also like to thank Mr. Phillips for hosting Dr. Brink and me at the Mississippi Museum of Natural Science for specimen comparison and for his assistance in specimen identification via email.

My geology professors at the University of Southern Mississippi each contributed to the success of this project. Dr. Mark Puckett allowed me to work in his research space

using the sink and sediment trap to collect excess sediment from sieving, and he also provided resources and consultation for identifying microfossils (foraminifera and ostracods). Dr. Frank Heitmuller also allowed me to use his lab equipment; without his sieves, sediment ovens, and scales, my research would have been significantly more challenging. Dr. Jeremy Deans carved time out of his schedule mid-semester to teach me how to use his microscope, microscope camera, and NIS-Element Advanced Research software to image my specimens. Each of these professors provided invaluable resources, and I am grateful for their support throughout my research period.

I thank Dr. Gary Stringer and Dr. David T. Dockery III for their contributions. Dr. Stringer, Professor Emeritus of Geology at the University of Louisiana at Monroe, provided assistance in identification of numerous otolith specimens, as well as a lesson in otolith morphology so that I could better understand their descriptions. Dr. Dockery, Registered Professional Geologist and Mississippi's State Geologist, provided literature on Mississippi Cretaceous fossils to aid in identification of gastropods, bivalves, and vertebrate organisms in my samples.

I would like to thank my parents for their encouragement and contribution of pie pans, and the rest of my family and friends for their continual support throughout this process as well, especially when I felt like my thesis was much bigger than me.

Finally, I would like to thank the Honors College at the University of Southern Mississippi for the opportunity to conduct undergraduate research, and the Drapeau Center for Undergraduate Research for the Eagle SPUR grant that funded many of the materials needed for my project.

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LIST OF ABBREVIATIONS

MMNS	Mississippi Museum of Natural Science
Ma	Million years
Pers. Comm.	Personal communication
CONOP	Constrained Optimism
FAD	First Appearance Datum
Gen. et sp.	Genus and species
Indet.	Indeterminate
cf.	Conferred to; specimen has not been definitively assigned, but confers to, or most closely compares to, the taxonomy following the notation
ppt.	Parts per thousand

CHAPTER I: INTRODUCTION

The Blue Springs site in northeastern Mississippi (Union County) has been studied since the 1980s, and it is noted for its rich, well-preserved, fossil faunal assemblages. The site provides insight into the paleoenvironmental conditions during the Maastrichtian (72.1 – 66 Ma, latest age of the Cretaceous Period) through abundant, well-preserved fossils, often preserving the original shell material of invertebrate organisms. Loose sediment and sedimentary concretions are also preserved and further contribute to the paleoenvironmental interpretations. This site records the fauna and environment of the Mississippi Embayment just prior to the Cretaceous-Paleogene extinction event, which is prevalently studied.

In 2018, Dr. Brink's Honors College Colloquium Class (Figure 1) visited this location during a field excursion. Most specimens were collected on the surface, including a variety of bivalves (*Exogyra*), gastropods (*Turritella*, *Anchura*), crabs (*Dakoticancer*), lobsters (*Hoploparia*), fish teeth (*Enchodus*, Figure 2), and others. The only *in situ* material was a fragmentary dentulous lower jaw of a mosasaur (Figure 3). A broken fragment of bone exposed at the surface was brought to Dr. Brink's attention by Honors student Olga Goupalova. Dr. Brink began to expose the jaw (Figure 4), but because more of it was imbedded in the rock, and proper excavation materials (plaster, burlap, etc.) were unavailable, the remaining jaw section (Figure 5) was excavated in 2019 (Figure 6). Other fauna collected during the 2019 expedition include lobsters (*Linuparus*), an ammonite (*Sphenodiscus* sp., Figure 7), and other genera in addition to the excavation of the rest of the mosasaur jaw (Figure 8).



Figure 1: Dr. Alyson Brink's Honors Colloquium class at the Blue Springs site, 2018 field excursion. G. Trocheset, bottom right; O. Goupalova, bottom middle. Photo courtesy of Dr. Brink.



Figure 2: A tooth from *Enchodus* sp., a ray-finned aulopiform fish, held by O. Goupalova. Image courtesy of Dr. Brink.



Figure 3: A fragmentary dentulous portion of a mosasaur lower jaw; dental pick for scale.



Figure 4: Dr. Brink excavated the visible portion of the mosasaur jaw.



Figure 5: Dr. Brink rediscovered the initial location of the 2018 mosasaur discovery to excavate the remaining portion of the jaw.



Figure 6: Volunteers on the 2019 field excursion to Blue Springs.



Figure 7: *Sphenodiscus* sp., a Late Cretaceous ammonite.



Figure 8: The mosasaurid dentulous jaw from both expeditions. The large crack in the center of the jaw separates the material from the 2018 trip (left) and the 2019 trip (right). Dental pick for scale. Image courtesy of Dr. Brink.

Although numerous specimens were previously collected, a third trip to Blue Springs was completed in 2021 to collect material in a way that reduced biases associated with previous surface collecting. During this trip, material was collected in bulk rather than from the surface to reduce preservation and collection biases. Preservation bias refers to the likelihood of an organism to become a fossil based on many characteristics: the presence of hard body parts, the chemical composition of the body parts, and the length of exposure on Earth's surface. For example, organisms with shells made of calcium carbonate will more easily dissolve in the presence of acidic groundwater than fossils with shells replaced by silica. In this case, there is a preservation bias for fossils with silicate shells, although they may not necessarily have been more abundant in life. Preservation potential is also affected by interaction with surface conditions through exposure to Earth's surface: precipitation, temperature changes, weathering and erosion, and interactions of living organisms. Collection bias can occur as a result of the individual collecting only what is noticed, whether intentional or not, based on familiarity or preference. For example, an individual may be more likely to find a fossil shark tooth (popular, easily identifiable, and usually visible with the naked eye) than an otolith (small inner ear bones of fish, not very commonly known, and easily mistaken for sediment) as a result of collection bias. Collecting samples in bulk reduces these biases, and it also provides a more accurate, representative collection of specimens for statistical analysis, including interpretations of relative abundance data.

A list of all invertebrate and vertebrate fossil occurrences at Blue Springs is currently lacking in the paleontological literature of Mississippi (G. Phillips, pers. comm.). Other authors have published peer-reviewed articles on the Blue Springs site

analyzing fossil assemblages including decapods (Bishop, 1983; Kornecki et al., 2017) and actinopterygians (Stringer et al., 2020), but a complete fossil faunal composition list has yet to be published. Such a list will benefit professional researchers interested in the fossil content of the Coon Creek Member of the Ripley Formation at Blue Springs, as well as amateur collectors interested in the paleontology of Mississippi.

Identifying, imaging, and publishing the fossils recorded in the sampled beds adds clarity the understanding of the paleontology and geology of Mississippi near the end of the Cretaceous Period, and more specifically, presents a clearer understanding of the paleoenvironment of Blue Springs. Evaluating the differences between the faunal assemblages of each bed reveals changes in paleoenvironmental conditions during deposition. All bulk and incidental fossil occurrences at the site are compiled with fossils recorded in published literature to create a faunal list for reference (Appendix A).

CHAPTER II: GEOLOGIC SETTING

In the Late Cretaceous, northeastern Mississippi was still submerged by the Mississippi Embayment, part of the Western Interior Seaway (Figure 9). At its maximum extent, the seaway was approximately 1,620 km wide and 4,800 km long, covering the middle of the United States and splitting North America into two landmasses (Roberts and Kirschbaum, 1995). The seaway reached its peak during a maximum global (eustatic) sea level in the Late Cretaceous as a result of tectonic processes related to subduction of the Farallon Plate and crustal loading onto the westernmost boundary of the North American Craton (Roberts and Kirschbaum, 1995). Shorelines fluctuated throughout the duration of the Western Interior Seaway and migrated eastward with its retreat. Tectonic uplift created internal drainage patterns and waning sea levels that ultimately resulted in the complete retreat of the seaway during the late Maastrichtian (Roberts and Kirschbaum, 1995), around the time of the deposition of the Blue Springs site.

Based on paleontological analysis of plants and animals, the paleoenvironment of the southeastern portion of the United States during the Maastrichtian was tropical with low to moderate amounts of precipitation, and there is no evidence of freezing temperatures or glaciation (Roberts and Kirschbaum, 1995).

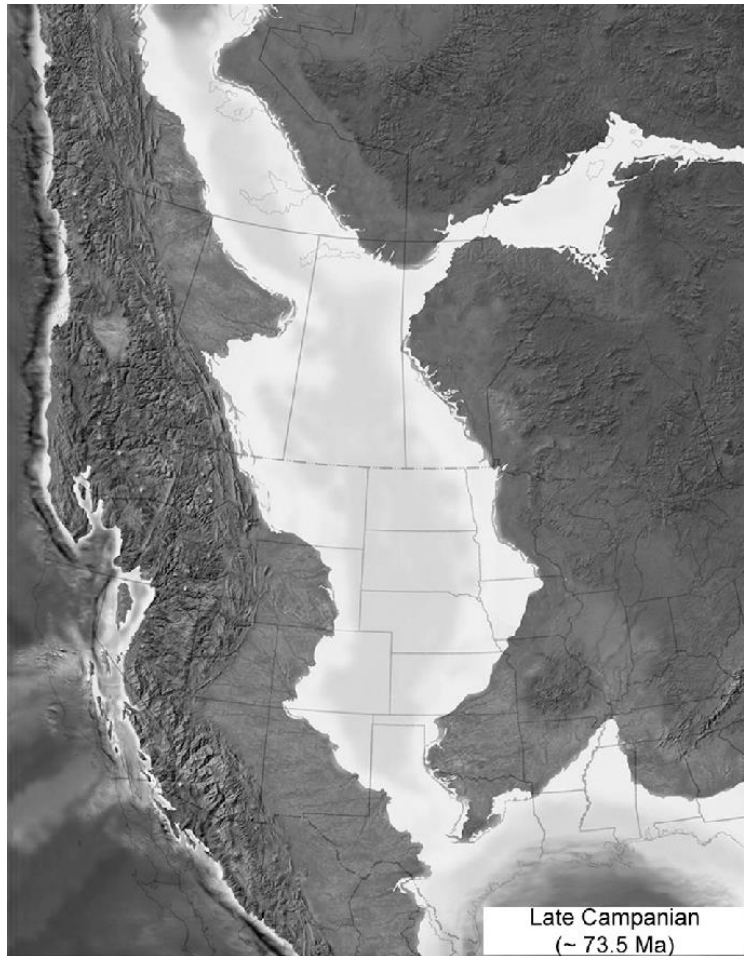


Figure 9: The extent of the Western Interior Seaway during the Late Campanian, 2.5 Ma before the deposition of the Blue Springs site in the Maastrichtian. From Lucas et al. (2016), ©2014 Ron Blakey, Colorado Plateau Geosystems, Inc.

The Blue Springs site in Union County, northeastern Mississippi, is an exposure of the Coon Creek Member (northeastern Mississippi and southwestern Tennessee) of the Ripley Formation, which spans across several southeastern states (Figure 10). At this locality, it is exposed as approximately 6 m of fossiliferous, green-gray, glauconitic, micaceous, clay-rich sand (Bishop, 2016). The site contains several fossiliferous layers, as well as an interval of phosphatic nodules that often contain fossil decapods, representing a period of erosion that left behind a phosphate nodule lag deposit (Bishop, 1983).

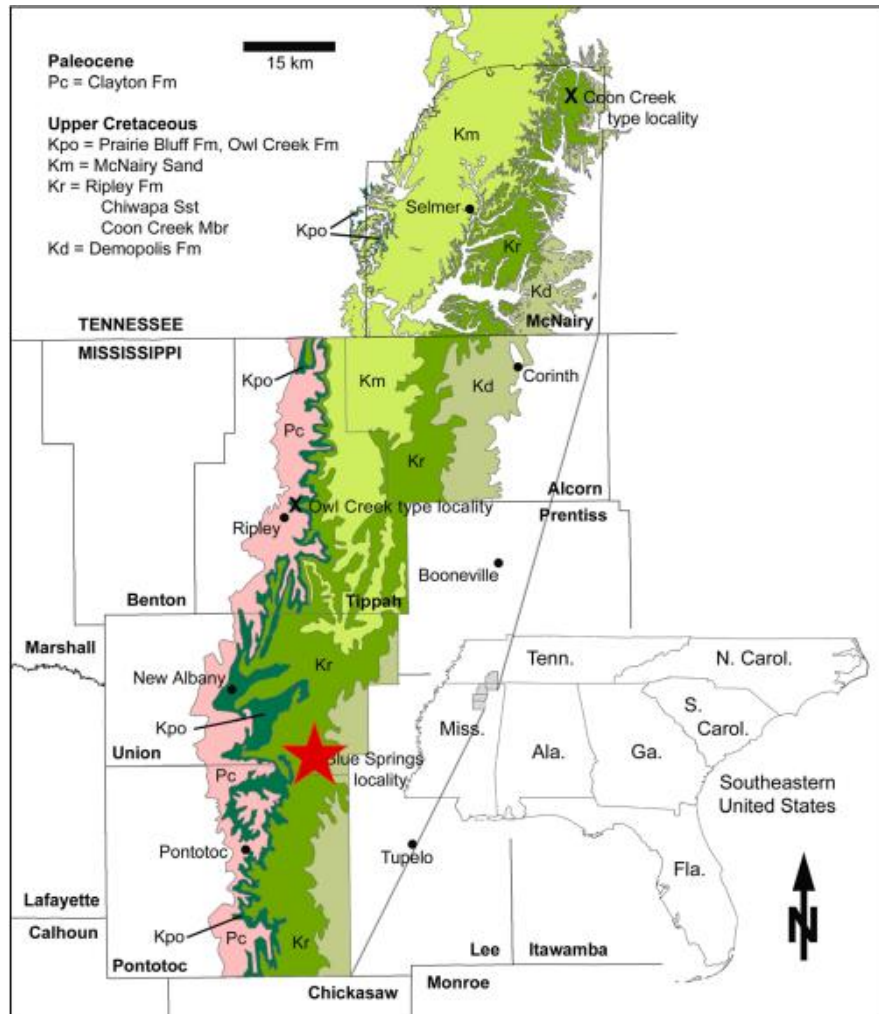


Figure 10: The Blue Springs locality (red star) in relation to the Coon Creek Member of the Ripley Formation (dark green). Modified from Stringer et al. (2020).

Stratigraphically (Figure 11), the Coon Creek Member lies at the base of the Ripley Formation and overlies the deep water chinks of the Demopolis Formation (Bishop, 1983). Because of the stratigraphic positioning of the fossiliferous mudstones of the Ripley Formation above the Demopolis Formation (indicative of a deep water environment) and below the McNairy Formation (sediments indicative of a deltaic and fluvial environment), the Ripley is interpreted as a time-transgressive shelf deposit from the Mississippi Embayment (Bishop, 1983).

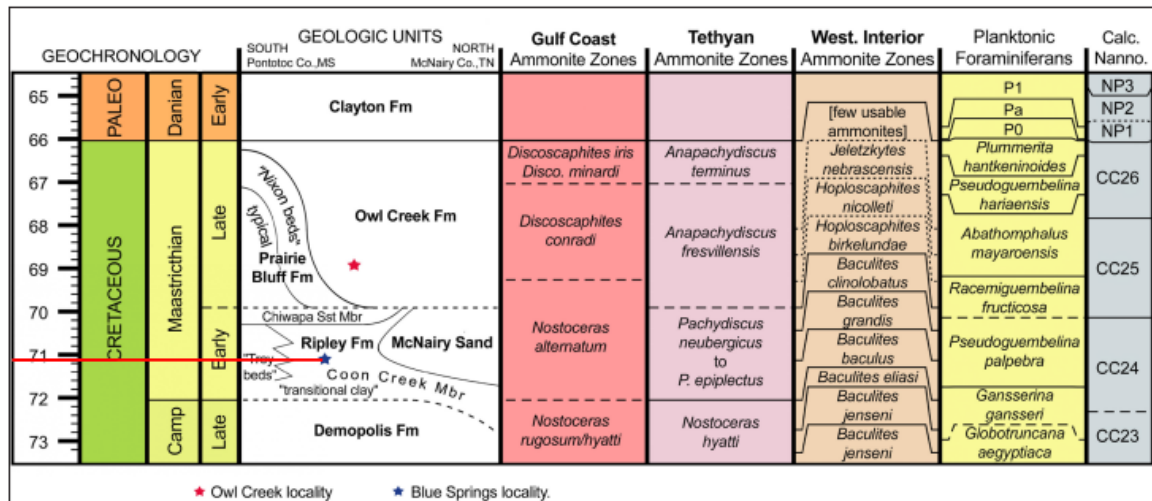


Figure 11: The age of the Blue Springs locality (blue star and red line) was constrained to around 71 Ma using biostratigraphy and chronostratigraphy. Modified from Stringer et al. (2020), produced with TS (TimeScale) Creator 7.3 (© 2005-2018 Geologic TimeScale Foundation), based on Ogg et al. (2016).

The age of rock units at the Blue Springs site has been constrained to the early Maastrichtian primarily using biostratigraphy and chronostratigraphy. In addition, Constrained Optimism (CONOP) software (Sadler, 2010) places the rocks and fossils deposited at the Blue Springs site in geologic time. A CONOP comparison of the Blue Springs section with the eastern Mississippi and central Alabama composite reference sections (including shared taxa and geologic events across all three sections) constrained the age of the site to between the First Appearance Datums (FADs) of ostracods *Escharacytheridea pinochii* and *Ascetoleberis hazardi*. In Mississippi, those FADs correlate in age with the late Campanian to late Maastrichtian (Figure 12) (Puckett, pers. comm.). The age was further constrained within this interval to the early – middle Maastrichtian by the abundance of the index fossil *Exogyra costata* (Bishop, 1983), and again further constrained to approximately 71 Ma using ammonite, planktonic foraminifera, and calcareous nannoplankton biostratigraphy (Figure 11) (Stringer et al., 2020).

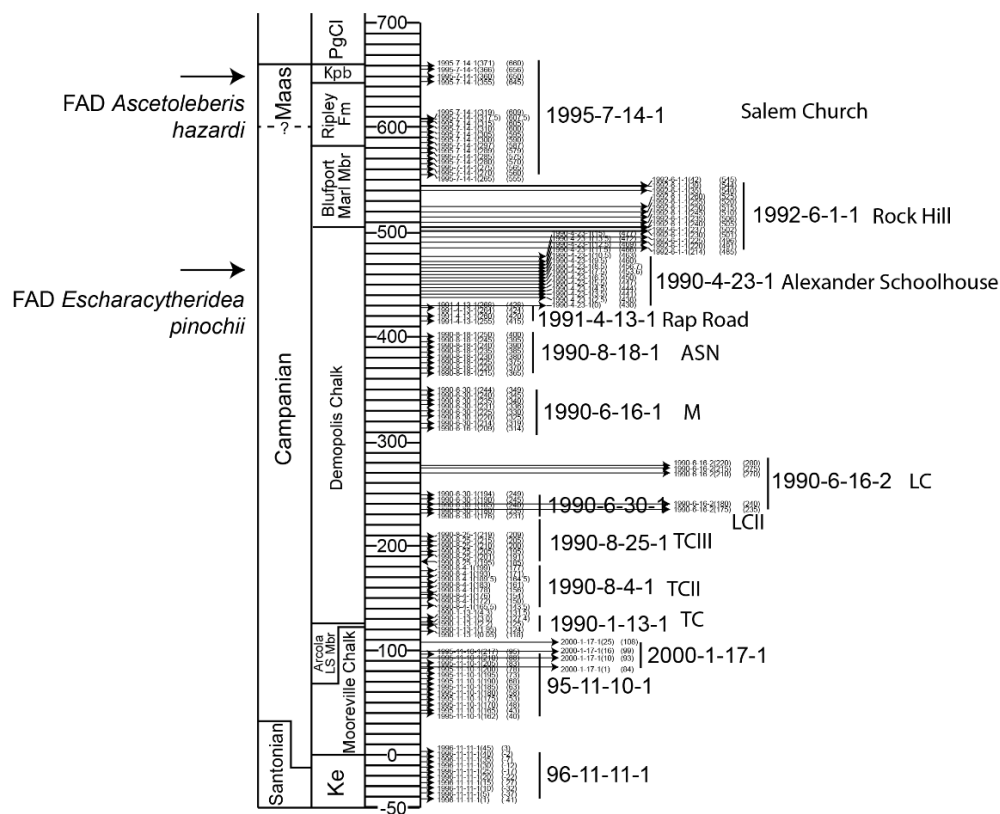


Figure 12: The age of the sediment and fossils at the Blue Springs locality was constrained in Mississippi based on FADs of ostracods using CONOP software. Unpublished figure of the FADs in relation to dated outcrops in Mississippi, from T.M. Puckett (pers. comm.).

The Blue Springs site has become overgrown with vegetation in recent years, but the outcrop remains largely accessible for observation and sampling (Figure 13). During initial studies, State Paleontologist George Phillips, Mississippi Museum of Natural Science (MMNS), assigned letters to each bed, beginning with Bed A at the base and progressing alphabetically upslope, ending with Bed L, the uppermost regolith layer. Three beds in particular, Bed C, Bed G, and Bed J (Figure 14) preserve diverse taxa and unique sedimentary compositions. Stringer et al. (2020) formally described and renamed the beds (Figure 15), and the highlighted beds in Figure 15 correspond to Phillips's

alphabetical names, as shown in Figure 14: Bed C is the Lower *Corbula* Bed, Bed G is the Pebble Bed, and Bed J is the *Exogyra-Pycnodonte* Bed.



Figure 13: G. Trochesset collecting nodules from the Pebble Bed, Bed G. Image courtesy of G. Phillips.



Figure 14: Beds sampled in bulk during the October 2021 trip to Blue Springs, marked by the author and team wearing reflective vests. The site is overgrown with vegetation, but the outcrop from which samples were taken remains accessible. Image courtesy of G. Phillips.

SCALE (m)	FACIES DESCRIPTIONS		UNIT
16	Soil / Regolith		
	Upper Sandstone	Highest sandy ledge; contains common ghost shrimp chelipeds and sea pen axes, often in vivo.	RIPLEY FM / Coon Creek Mbr
14	<i>Exogyra-Pycnodonte</i> Bed	Fine sandy to silty clay with abundant large <i>Exogyra costata</i> and <i>Pycnodonte mutabilis</i> , many exhibiting boring sponge traces (<i>Entobia</i>). Burrowing conspicuous in places. Vertebrate fossil accumulation at base includes plesiosaur bones.	
6	Middle Sst	Ledge marked by muffin crab <i>Avitelmessus</i> .	
	Aragonitic Clay Bed	Clay bed with fragile aragonitic mollusk fauna.	
	Pebble Bed	Glauconitic, fine sandy, clay with phosphatic pebbles, well-preserved crustaceans, and marine vertebrates.	
4	Aragonitic Clay Bed	Clay bed with fragile aragonitic mollusk fauna and poorly preserved crustaceans.	
	Upper <i>Corbula</i> Bed	Rich in tiny macroinvertebrate shells, namely the clam <i>Corbula</i> and the coral <i>Micrabacia</i> ; otoliths common.	
2	Aragonitic Clay Bed	Clay bed with fragile mollusks and crustaceans.	
	Lower <i>Corbula</i> Bed	Rich in tiny macroinvertebrate shells, namely the clam <i>Corbula</i> and the coral <i>Micrabacia</i> ; otoliths common.	
	Aragonitic Clay Bed	Burrowed interval with larger mollusks.	
	Lower Sst	Ledge containing echinoids, bryozoans, and belemnites.	

Figure 15: The beds of Blue Springs, as described by Stringer et al. (2020). The Lower *Corbula* Bed corresponds to "Bed C," the Pebble Bed corresponds to "Bed G," and the *Exogyra-Pycnodonte* Bed corresponds to "Bed J." Figure modified from Stringer et al. (2020).

CHAPTER III: MATERIALS AND METHODS

Fossiliferous matrix was collected from the Blue Springs site on October 21, 2021. With assistance from G. Phillips (MMNS), the collection team sampled the three most fossiliferous layers of the Coon Creek beds at the locality (Figures 14 and 15). Each layer was sampled in bulk and filled one five-gallon plastic bucket (Figure 16), resulting in approximately 22.7 kg of matrix from each layer. The weathered surfaces of the unconsolidated highest and lowest beds were removed prior to bulk sampling to expose fresh material that had not been impacted by weathering and erosion. In each bed, fragile macrofossils were removed from the bulk, imaged with an iPhone XR, and individually wrapped and stored in the top portion of the sample bucket for best preservation.



Figure 16: Plastic buckets were labeled and filled with sediment from each bed.

The first sample was collected from the highest location, the *Exogyra-Pycnodonte* Bed (Bed J). Based on stadia rod measurements (Figure 17), Bed J occurs 47 cm above the subjacent Middle Sandstone (“muffin crab”) Bed (Bed I). A total of 23.2 kg of matrix and fossils were collected from the freshly exposed sediment within an area of approximately one square meter.



Figure 17: Measurement of Bed J with stadia rod; Dr. Brink (left) and G. Trochesset (right). Photo courtesy of G. Phillips.

The second sample was collected from the Pebble Bed (Bed G). This bed is known for containing phosphatic nodules of matrix often preserving decapod remains. Upon looking for a sample location for this bed, the team came upon a very recent (within a day or two) excavation by an unknown individual. As a result, the fresh surface was exposed, and removal of the weathered surface was not required. The team collected

24.9 kg of matrix, consisting primarily of large blocks that contained many exposed invertebrate fossils, including gastropods and bivalves (Figure 18).



Figure 18: Large block from Bed G containing fragmentary gastropod and bivalve material, including an approximately 6 cm long impression preserving the original shell material of *Trigonia* sp.

The third sample was collected from the lowest of the three beds, the Lower *Corbula* Bed (Bed C), in much the same manner as that from Bed J. A 23.7 kg sample was collected from an area of approximately one square meter of Bed C.

“Incidental” specimens were obtained from each of the three layers in addition to the bulk samples. These specimens were collected from the same beds, adjacent to each of the bulk sampling locations, to record taxa that may not appear in the bulk samples. They are listed in the faunal composition but are not included in the statistical analysis or relative abundance data of this project.

Each bulk sample was weighed using a Weight Gurus Appsync Smart Scale standard house scale. The unconsolidated nature of Beds C and J allowed sediment to be removed most easily from fossil material by wet sieving, so they were processed first. The matrix from these beds was wet sieved using sieves of U.S. Standard Sizes 10, 20, 30, and 40, with mesh holes ranging in size from 2 mm to 425 μm , respectively. The sieves were stacked under a sink faucet (Figure 19); the largest particles were caught in the uppermost sieve (Figure 20), and finer material was caught in sieves with progressively smaller mesh openings. The finest sediment passed through the lowest sieve into a sediment trap in the sink drainpipe to prevent clogging (Figure 21). Resulting concentrate from each sieve was placed into labeled aluminum pie pans (Figure 22) and dried at 100° F in a Blue M Electric Company laboratory oven (Figure 23). The dried concentrate was placed into labeled plastic sample bags, and it was weighed using an Ohaus Scout II SC6010 portable scale (Figure 24). Visible, fragile fossil material was removed during sieving and placed into the containers of bulk picked specimens.



Figure 19: U.S. Standard Sieves 10 - 40, stacked in this manner during sieving



Figure 20: Sieve size 10, showing wire mesh with 2 mm gaps, which caught the largest particles.



Figure 21: The sink was connected to a sediment trap (lower left, purple) to prevent the drain from clogging with sediment.



Figure 22: The concentrate from each sieve was placed in labeled aluminum pie pans to dry. The concentrate from the largest sieve size is pictured on the left, decreasing in size to the right.



Figure 23: Blue M Electric Company laboratory oven.

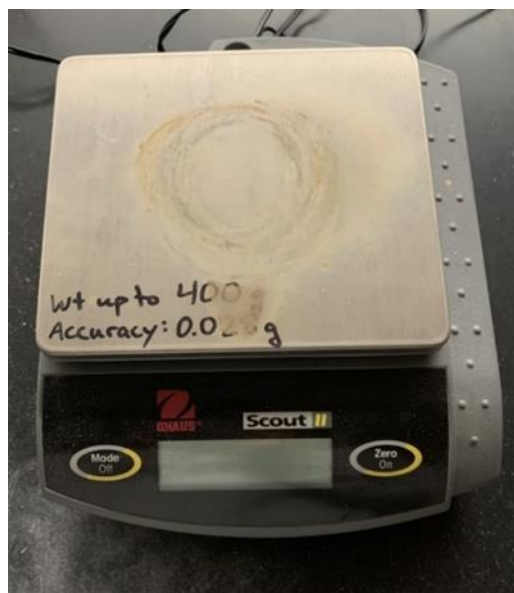


Figure 24: Ohaus Scout II SC6010 portable scale.

Sieving approximately one fourth of the Lower *Corbula* Bed (Bed C) produced 611 g of concentrate. After observing dust-sized particles remaining in the finer sieved concentrate and aggregated sediment (round particles about 1 cm in diameter) in the coarser concentrate, the concentrate was completely dried and dry sieved, and the coarser sediment was wet sieved again. Drying the sediment prior to wet sieving reduced the amount of mud particles in the concentrate and broke down the larger aggregates.

The *Exogyra-Pycnodonte* bed (Bed J) was initially processed in the same way as Bed C, but wet sieving resulted in the formation of small, subrounded, peloidal grains that did not disaggregate with repeated cycles of soaking, wet sieving, and oven drying. The sediment from Bed C was a sandy marl that passed easily through the sieves, leaving minimal sediment residue in the concentrate. In contrast, Bed J had more clay, and the more clay a sample contains, the more likely it is to form aggregates. This is because clay particles are small and have a negative electric charge at their surface, so they readily attract other particles. To combat this problem in Bed J, Dawn Platinum dish soap (Procter & Gamble) was added to the aluminum pie pans of sediment and water, and the pans were agitated to distribute the soap. The surfactant properties of the Dawn initiated disaggregation, and the peloidal grains present in the sample disaggregated in subsequent wet sieving. Approximately one-sixth of the collected bulk from Bed J was sieved, which resulted in 59.4 g of fairly “clean” concentrate. Bed G was not processed.

The concentrates from Bed J and Bed C were picked using a Nikon SMZ-2T microscope (Figure 25), an AmScope lamp, and a paintbrush. Specimens in the concentrate were separated and stored in small, labeled sample bags in a labeled plastic storage box. Small specimens, including foraminifera, and fragile specimens, including

some scaphopods and delicate vertebrate material, were stored in size 00, 1, or 3 gel capsules inside of the sample bags, depending on their size. Currently, the picked specimens are stored in this manner, and eventually, they will be repositied into the collections at MMNS in Jackson, MS.



Figure 25: Nikon SMZ-2T microscope and AmScope lamp.

The specimens were imaged using a Nikon SMZ 745T microscope (Figure 26), a Nikon DS-Fi3 camera, and NIS-Element Advanced Research software, with occasional use of putty to securely position the specimens. Resulting specimen plates (Plates 1 – 14) were created using GIMP software to scale and position the images on a plain, solid background.

Specimens were identified using peer-reviewed literature sources and experts in the fields of otoliths, ostracods, and Cretaceous fauna. Some of the foraminifera were

stained with food coloring to enhance the view of the chambers, aperture, and surface features for identification.

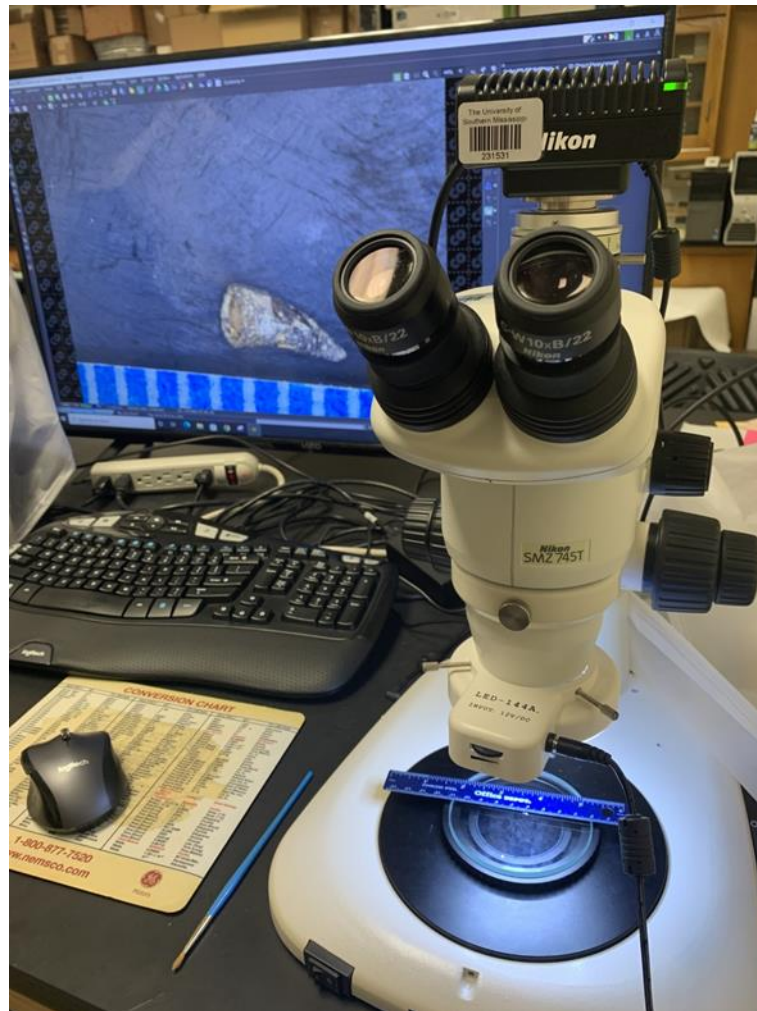


Figure 26: A Nikon SMZ 745T microscope, a Nikon DS-Fi3 camera, and NIS-Element Advanced Research software were used to image the picked specimens.

CHAPTER IV: SYSTEMATIC PALEONTOLOGY

Following is the systematic paleontology for taxa from Bed J bulk material.

Kingdom RHIZARIA Adl et al., 2005
Phylum FORAMINIFERA d'Orbigny, 1826
Class NODOSARIATA Mikhalevich, 1993
Order NODOSARIIDA Calkins, 1933
Family NODOSARIIDAE Ehrenberg, 1838
Genus FRONDICULARIA Defrance in d'Orbigny, 1826
Frondicularia frankei Cushman, 1936
Plate 1: A-C

Material. 3 fragmentary tests.

Description. Specimens are mostly complete, some with broken ends not preserving the aperture or proloculus. Average test length 3 mm, average breadth 1 mm. Tests are elongate and compressed, exhibiting biserial growth and steeply angled chambers individually ornamented with raised longitudinal costae. Aperture terminal, at the end of a short neck (not imaged).

Discussion. Assignment to *Frondicularia frankei* was based on comparison with other specimens of *F. frankei* from the Ripley Formation (Cushman, 1946; p. 89; pl. 35, fig. 14-16) and the distinct costae that ornament individual chambers rather than the full test (Cushman and Deaderick, 1944).

Genus NODOSARIA Lamarck, 1816

Nodosaria affinis (Reuss, 1845)

Plate 1: D-G

Material. 212 tests: 124 complete microspheric forms, 67 complete megalospheric forms, 21 test fragments.

Description. All specimens exhibit uniserial growth and have bulbous chambers with longitudinal costae. Microspheric forms taper from the wider apertural end to the narrower posterior end toward the proloculus, with chambers increasing in size with distance from the proloculus. Megalospheric forms have chambers that retain generally the same width throughout the length of the test, with the terminal chambers being the same size, and chambers between being slightly smaller. Fragmentary segments of tests have the same bulbous shape and longitudinal costae, but their form is indeterminate because only 1-4 chambers are preserved without showing the overall test morphology. Average length of complete microspheric forms is 5 mm, and breadth is 0.2 mm at the tapered proloculus and 0.6 mm at the greatest width. Megalospheric forms are 4 mm in length and 0.6 mm in width.

Discussion. Tests were assigned to *Nodosaria affinis* based on comparison to other *N. affinis* specimens from the Ripley Formation (Cushman, 1946; p. 70; pl. 25, fig. 8-12). Distinguished from *Dentalina* by more widely spaced longitudinal costae and a more symmetrical final chamber, rather than an angled, asymmetrical, tear-shaped final chamber as in *Dentalina* (Cushman, 1946; p. 64; pl. 23-24).

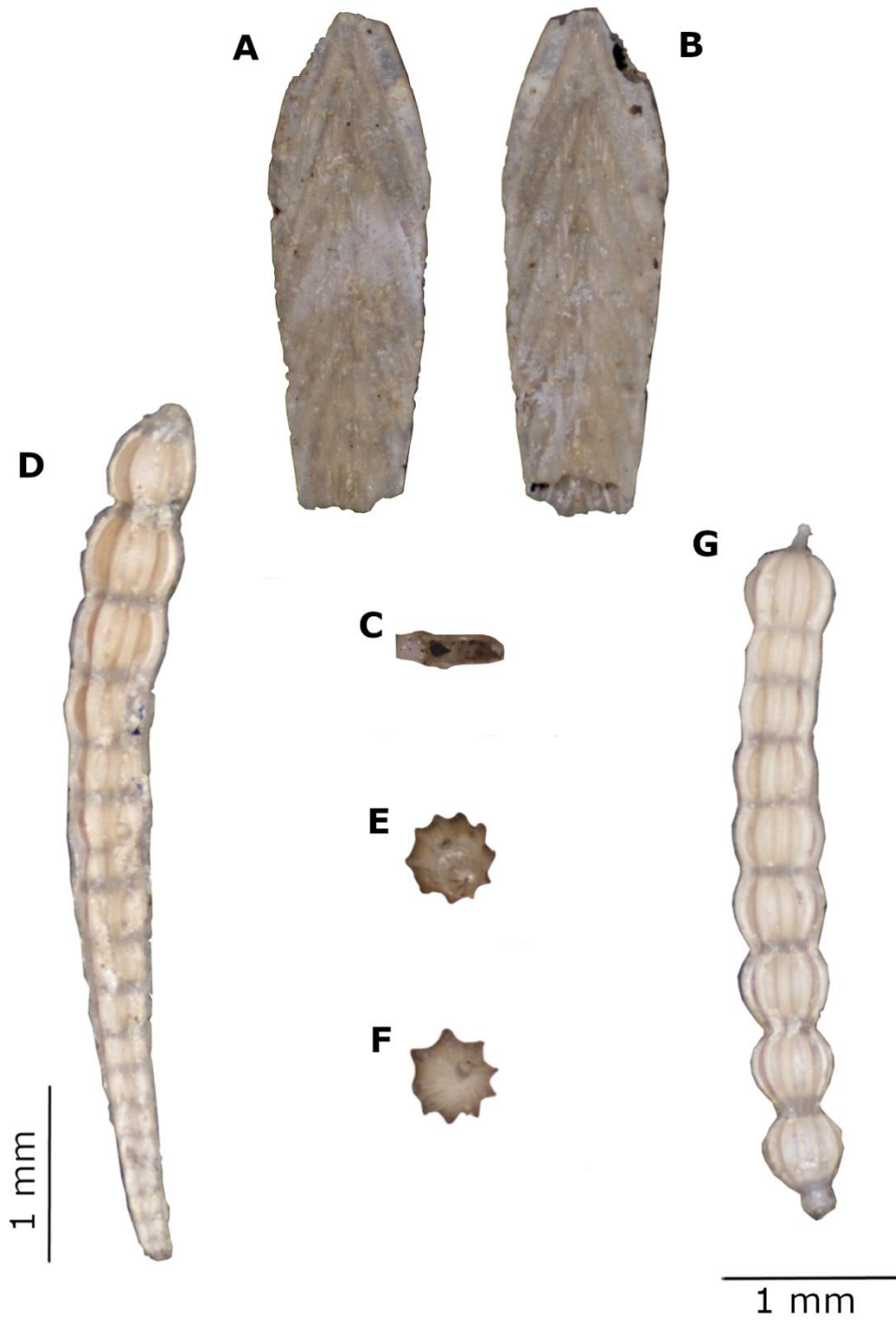


Plate 1: A-B) *Frondicularia frankei*, lateral views. C) *F. frankei*, apertural view. D) *Nodosaria affinis*, microspheric form, lateral view. E) *N. affinis*, microspheric form, apertural view. F) *N. affinis*, megalospheric form, apertural view. G) *N. affinis*, megalospheric form, lateral view.

Order VAGINULINIDA Mikhalevich, 1993
Family VAGINULINIDAE Reuss, 1860
Genus ROBULUS Montfort, 1808

Robulus stephensoni (Cushman, 1939)
Plate 2: A-B

Material. 577 complete tests.

Description. Compressed, planispiral tests with an average of 10 limbate, curved, unornamented chambers. Slightly umbonate with a narrow keel. Aperture radiate and terminal on the peripheral angle. Average diameter 2 mm, thickness 0.7 mm.

Discussion. The chamber curvature and presence of a narrow keel and slight umbo are most similar to characteristics of *R. stephensoni* from the Ripley Formation (Cushman, 1946; p. 55; pl. 18, fig. 12-13).

Robulus münsteri (Roemer, 1839)

Material. 152 complete tests.

Description. Tests exhibit planispiral growth with an average of 12 limbate, curved, unornamented chambers. Compressed and umbonate with a sharp keel. Aperture radiate and terminal on the peripheral angle. Diameter less than 2 mm.

Discussion. These specimens were distinguished from *R. stephensoni* based on a much more prominent umbo and sharper keel, which more closely resembles the morphology of *R. münsteri* from the Ripley Formation (Cushman, 1946; p. 53; pl. 17 fig. 3-9).

Robulus spissocostatus (Cushman, 1938)

Plate 2: C

Material. 104 complete tests.

Description. Compressed, planispiral tests with an average of 11 limbate, curved, unornamented chambers. Chambers separated by very distinct, rounded, thick, raised sutures, which cover the umbo and radiate into a distinct spiral pattern. Umbonate with a slight, rounded keel. Aperture radiate on the outer angle of the terminal chamber. Diameter less than 2 mm.

Discussion. Assigned to *R. spissocostatus* because of the distinctive spiral pattern created by the raised sutures over the umbo. Compare most favorably to other Cretaceous specimens of *R. spissocostatus* (Cushman, 1946; p. 52-53; pl. 16, fig. 11-14; pl. 17, fig 1).

Robulus pondi (Cushman, 1931)

Plate 2: D

Material. 82 complete tests.

Description. Compressed, planispiral tests with distinct knobby angles along the periphery of the chambers. Average of 11 smooth chambers in the final coil. Flattened umbo, polygonal keel. Medium sized tests, not exceeding diameters of 1.5 mm.

Discussion. Assigned to this species because of the distinctive polygonal keel resulting from the angles of the sutures. Very similar to other specimens of *R. pondi* from the Ripley Formation (Cushman, 1946; p. 52; pl. 16, fig. 1-5).

Robulus sp.

Material. 117 fragmentary tests.

Description. Tests are fragmentary or heavily weathered; generally tan but are gray in weathered areas, especially near the umbo. Chambers grow in a planispiral coil.

Discussion. Enough of the test is preserved to document that the specimens are planispiral and belong to *Robulus* (Cushman, 1946; pl. 16-18), but they cannot be assigned to a species due to inability to see the complete chamber morphology, central pattern, and presence/absence of a keel. Specimens were not imaged due to their fragmentary nature and/or degree of weathering.

Genus VAGINULINA d'Orbigny, 1826

Vaginulina webbevillensis Carsey, 1926

Plate 2: E-F

Material. 149 complete tests.

Description. Large, compressed, elongate tests with numerous chambers that increase in width toward the apertural end with each chamber addition. Tests are generally between 6-7 mm in length and 2-3 mm in width. Dorsal edge is flattened, ventral edge is convex. Variation occurs between tests in the shape of the ventral edge. Some specimens (Plate 2:E) have a generally smooth, curved ventral edge. Other specimens (Plate 2:F) have a depression near the peripheral center of the keel. Aperture is radiate and terminal on the dorsal angle, and it protrudes slightly.

Discussion. Compare most similarly to other Cretaceous specimens of *V. webbevillensis* (Cushman, 1946; p. 81; pl. 30, fig. 5-10). The size, chambers, aperture, and general shape are indicative of this species.

Vaginulina taylorana Cushman, 1938
Plate 2: G-H

Material. 19 complete tests.

Description. Tests are elongate and compressed. Numerous chambers that are wider than long, with a distinctive bulbous ornamentation in the middle of some sutures. Tests average 3-4 mm in length, and width is no more than 0.5 mm. Aperture is radiate and terminal on the dorsal angle, and it protrudes slightly.

Discussion. Most similar to other Cretaceous specimens of *V. taylorana* (Cushman, 1946; p. 81-82; pl. 28, fig. 28-29).

Vaginulina wadei Kelley, 1929
Plate 2: I

Material. 55 complete tests.

Description. Test compressed and elongate, with a straight dorsal edge and a convex, tapered ventral edge. Chambers grow wider with each addition and are separated by distinctive sutures, which are strongly limbate and straight or slightly curved. Test wall is ornamented with longitudinal costae, which are most evident near the proloculus. Aperture is radiate and terminal on the dorsal angle, and it protrudes slightly. Tests do not exceed 3 mm in length or 1 mm in breadth.

Discussion. Compared with other specimens of *V. wadei* from the Coon Creek Member of the Ripley Formation (Cushman, 1946; p. 79; pl. 29, fig. 1-6). Distinguished from *V. webbervillensis* by a smaller size and more strongly limbate sutures (Cushman, 1946).

Vaginulina sp.

Material. 322 test fragments.

Description. Numerous test fragments resemble the compressed nature, chamber structure, general shape, and width of other *Vaginulina* tests in this sample that have been assigned to *V. webbervillensis* and *V. wadei*.

Discussion. Although the test fragments can be assigned to *Vaginulina*, they cannot be further designated because their fragmentary nature does not preserve test features necessary for assignment. They were not imaged due to their fragmentary nature.

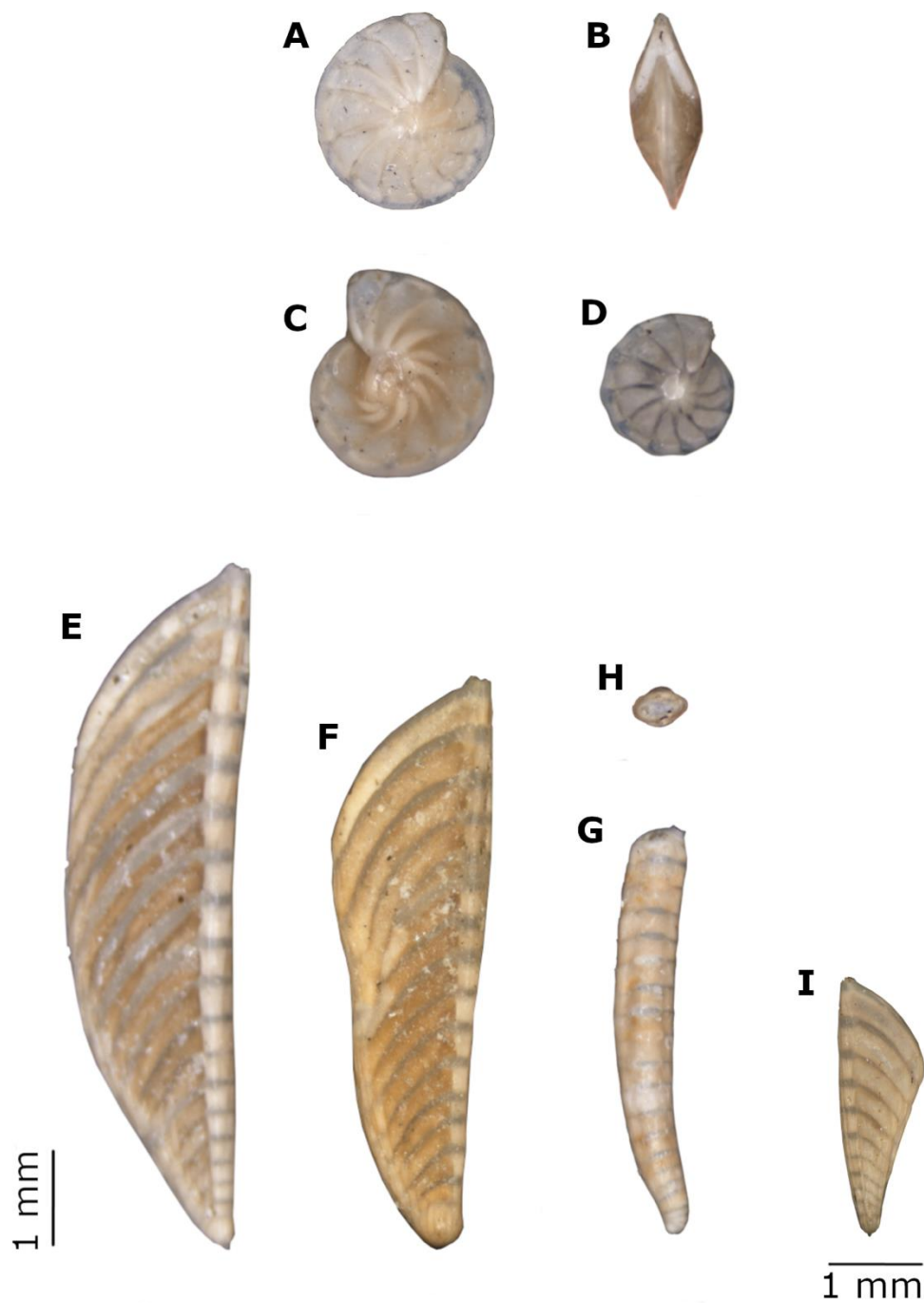


Plate 2: A) *Robulus stephensoni*, lateral view. B) *R. stephensoni*, apertural view. C) *Robulus spissocostatus*, lateral view. D) *Robulus pondi*, lateral view. E-F) *Vaginulina webbervillensis*, lateral views. G) *Vaginulina taylorana*, lateral view. H) *V. taylorana*, apertural view. I) *Vaginulina wadei*, lateral view.

Order POLYMORPHINIDA Mikhalevich, 1980
Family POLYMORPHINIDAE d'Orbigny, 1839
Genus PSEUDOPOLYMORPHINA Cushman and Ozawa, 1928

Pseudopolymorphina cuyleri Plummer, 1931
Plate 3: A-C

Material. 3 tests: 2 complete tests, 1 fragmentary test.

Description. Tests are compressed and tapered. Chambers form through biserial growth and become wider in breadth as height is added. Aperture is terminal. The fragmentary test is a cross-sectional fragment; the chambers, growth pattern, and aperture can be seen more clearly in this view.

Discussion. These specimens are most similar to other Cretaceous specimens of *P. cuyleri* (Cushman, 1946; p. 98, pl. 41, fig 6).

Genus BULLOPORA Quenstedt, 1856

Bullopore laevis (Sollas, 1877)
Plate 3: D-E

Material. 17 complete tests.

Description. 16 tests attached to various fragmentary shells. 1 test attached to *Fronicularia webbervillensis*. Smooth-walled, oval chambers occur mostly in a single series, with occasional occurrences of chambers branching into two series.

Discussion. Distinguished from *Bullopore tuberculata* because *B. laevis* is smooth walled, where *B. tuberculata* has a hispid texture (Cushman, 1946; p. 99; pl. 42, fig. 5-7). Most similar to other Cretaceous specimens of *B. laevis* (Cushman, 1946; p. 98-99; pl. 42, fig. 1-4).

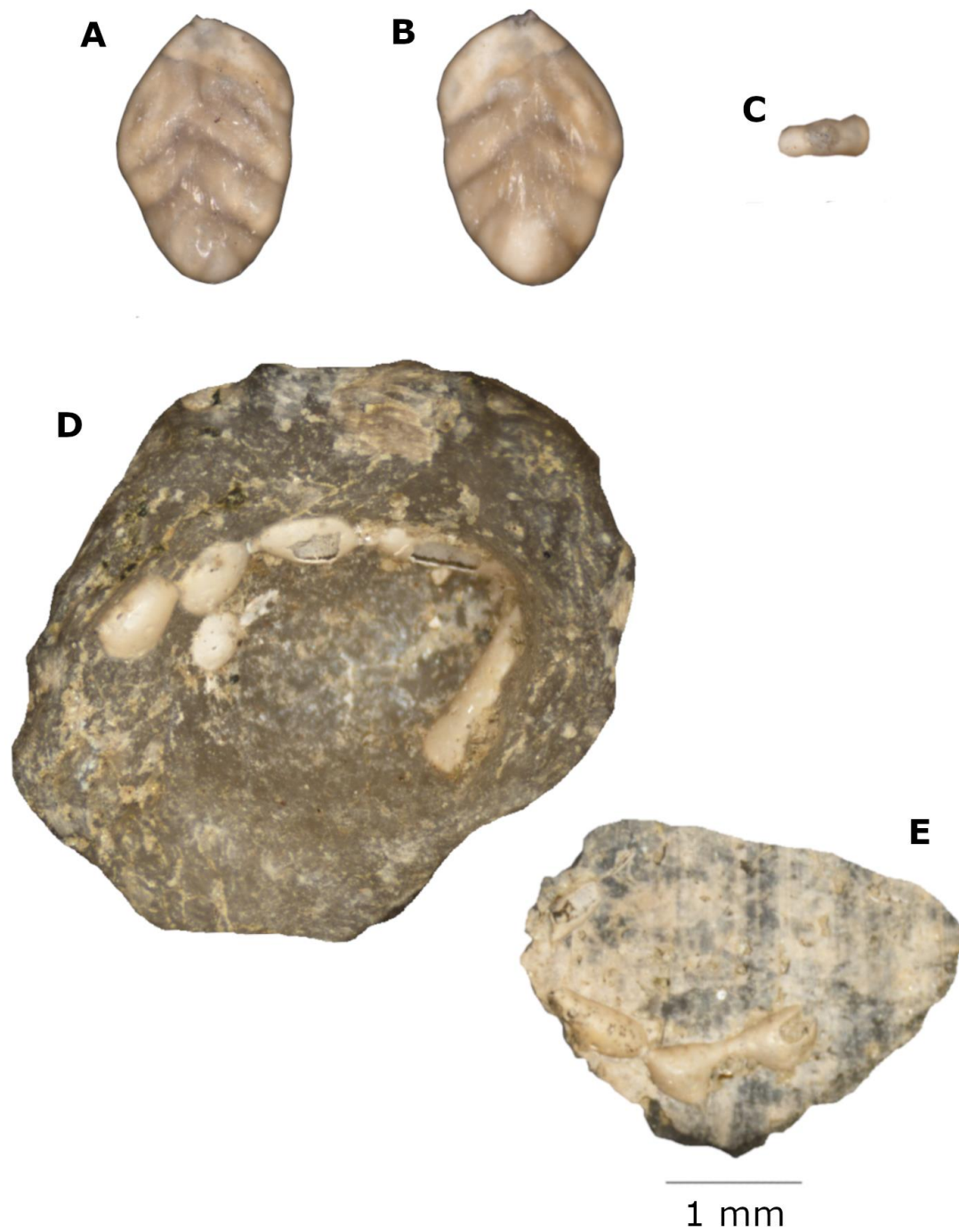


Plate 3: A-B) *Pseudopolymorphina cuyleri*, lateral views. C) *P. cuyleri*, apertural view. D-E) *Bullopora laevis* specimens on shell fragments, lateral view.

Class GLOBOTHALAMEA Pawlowski et al., 2013
Order ROTALIIDA Delage and Hérourard, 1896
Family CIBICIDIDAE Cushman, 1927
Genus CIBICIDES Montfort, 1808

Cibicides harperi (Sandidge, 1932)

Plate 4: A-B

Material. 23 complete tests.

Description. Umbilical/ventral side is flattened, spiral/dorsal side is conical. The center of the umbilical side is depressed and covered by clear test material, and the spiral side has a small, raised umbo. The final coil generally has 9 chambers with an aperture angled on the penultimate chamber. Tests are smaller than other foraminifera observed in Bed J, averaging 0.6 mm in width and 0.7 mm in length.

Discussion. Compared to other specimens of *C. harperi* from the Ripley Formation (Cushman, 1946; p. 159; pl. 65, fig. 5-7).



Plate 4: *Cibicides harperi*. A) spiral view and B) umbilical view.

Kingdom ANIMALIA
Phylum MOLLUSCA Linnaeus, 1758
Class BIVALVIA Linnaeus, 1758
Order PECTINIDA Gray, 1854
Family ANOMIIDAE Rafinesque, 1815
Genus ANOMIA Linnaeus, 1758
Anomia argentaria Morton, 1833
Plate 5: A-C

Material. 14 left valves.

Description. These fossil valves preserve original shell material that creates a glossy, reflective sheen. Valves are circular with a concave medial posterior portion. Valves flatten towards the anterior and lateral edges. Concentric growth lines are visible. Valves average 3.5 mm in diameter.

Discussion. Most similar to other Late Cretaceous shells of *A. argentaria* with distinctive sheen and concavo-convex shape (Dockery, 2020; p. 87, MGS figured specimens 2648 and 2649).

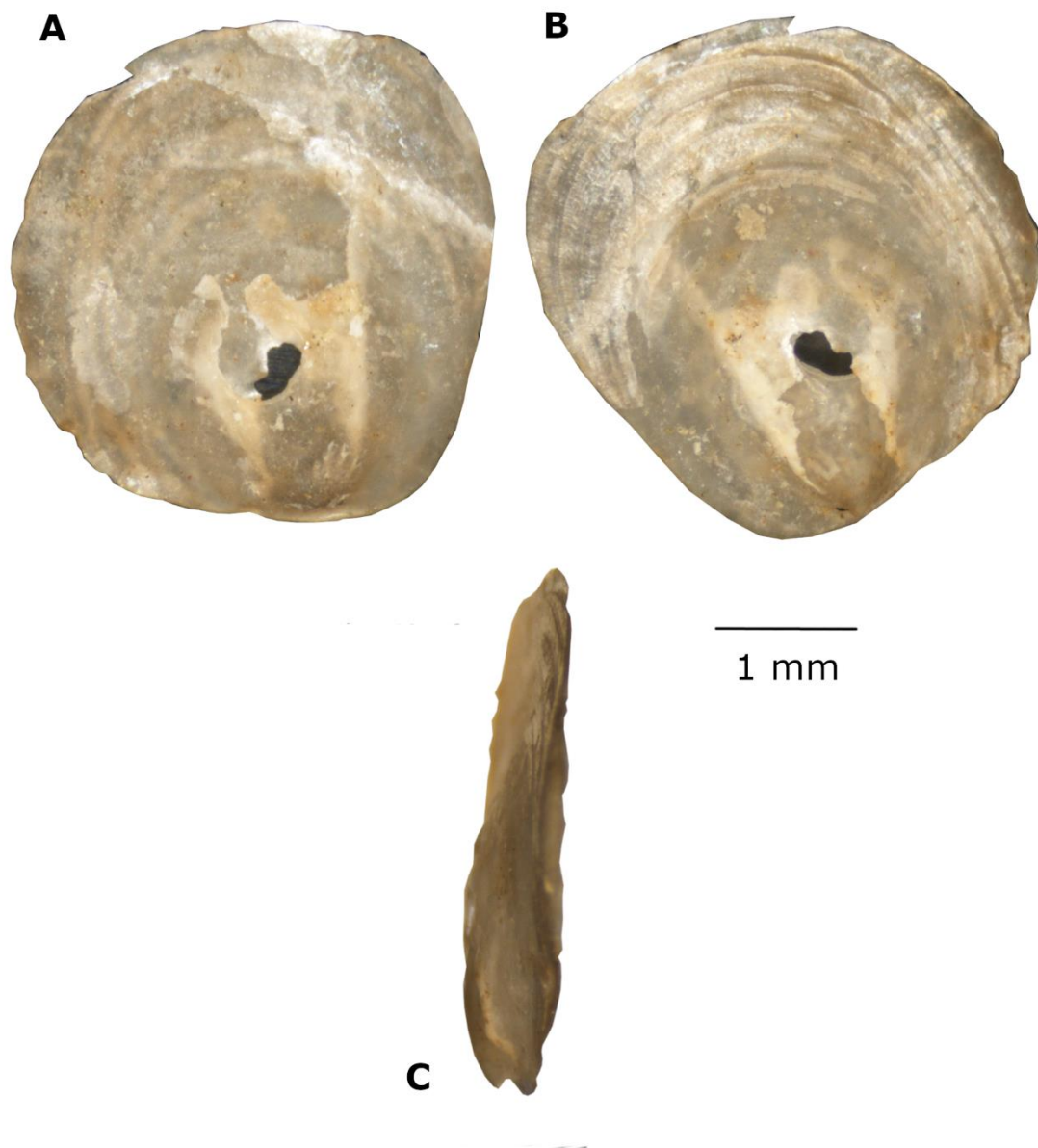


Plate 5: *Anomia argentaria* left valve; A) posterior, B) anterior, and C) lateral views.

Class GASTROPODA Cuvier, 1795
Order CAENOGASTROPODA Cox, 1959
Family TURRITELLIDAE Lovén, 1847
Genus TURRITELLA Lamarck, 1799

Turritella trilira Conrad, 1860

Plate 6: A-B

Material. 2 apexes of adult shells.

Description. Conically raised apex with three spiral carinae on each whorl. Shell surface is smooth between carinae. Aperture is subcircular. Shells average 1.8 mm in length and 1.1 mm in width.

Discussion. The presence of three spiral carinae on each whorl is distinctive of this species (Dockery, 1993). Most similar to other specimens of *T. trilira* from the Coffee Sand, comparable to those of the Coon Creek Member of the Ripley Formation (Dockery, 1993; p. 49-50; pl. 8, fig. 1-4).

Genus LAXISPIRA Gabb, 1877

Laxispira cf. *lumbricalis* Gabb, 1877

Plate 7: A

Material. 2 fragmentary partial shells.

Description. Shells are fragmented on both ends, and it is evident they are part of a larger shell. The shells exhibit a regular loosely coiled growth pattern in which whorls do not touch, and the longitudinal expansion rate indicates that the complete shells would have had a high spire. Shells have abundant lirae ornamentation on each whorl.

Discussion. Fragmentary shells were compared to complete specimens of *L. lumbricalis* from the Coffee Sand from the Cretaceous (Dockery, 1993; p. 51-52; pl. 8, fig. 4-9; closest to fig. 5-6). Assignment was based on a similar high longitudinal expansion rate

and numerous lirae on whorls, but because the shells are fragmentary, they are only conferred to this species.

Order, Family, Gen. et sp. indet.
Plate 6: C-I

Material. 3 fragmentary shells.

Description. Three distinct, fragmentary, heavily weathered shells exhibiting an evident coiled growth pattern. Shell fragments range in length from 0.6 mm to 1.6 mm. and vary in color from white to brown.

Discussion. The fragments are gastropods because they are univalve molluscs with a whorl shape around a central axis (Stoliczka, 1868), but they cannot be further assigned due to their fragmentary nature. It is likely that the shells represent three different gastropod species, but they can only be assigned to that class due to incomplete preservation.

Order, Family, Gen. et sp. indet.
Plate 7: B-E

Material. 4 gastropod internal molds.

Description. The internal molds preserve the structure and internal morphology of the gastropods, but little to no shell material is preserved.

Discussion. Molds are coiled like gastropods (Stoliczka, 1868), but without shell material or diagnostic external characteristics, they cannot be assigned further.

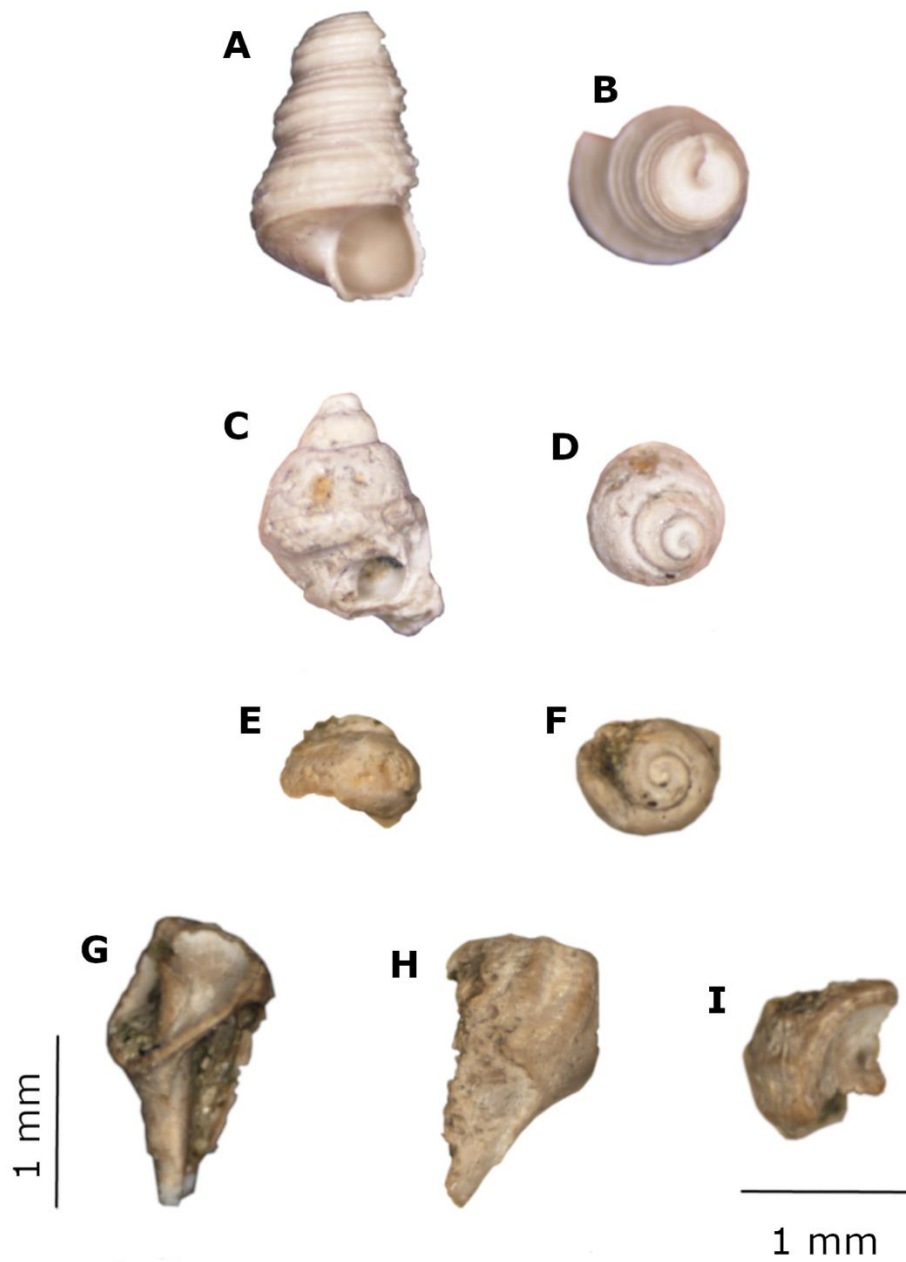


Plate 6: A-B) *Turritella triliria*, apertural view and apex view. C-I) Fragmentary gastropod shells.

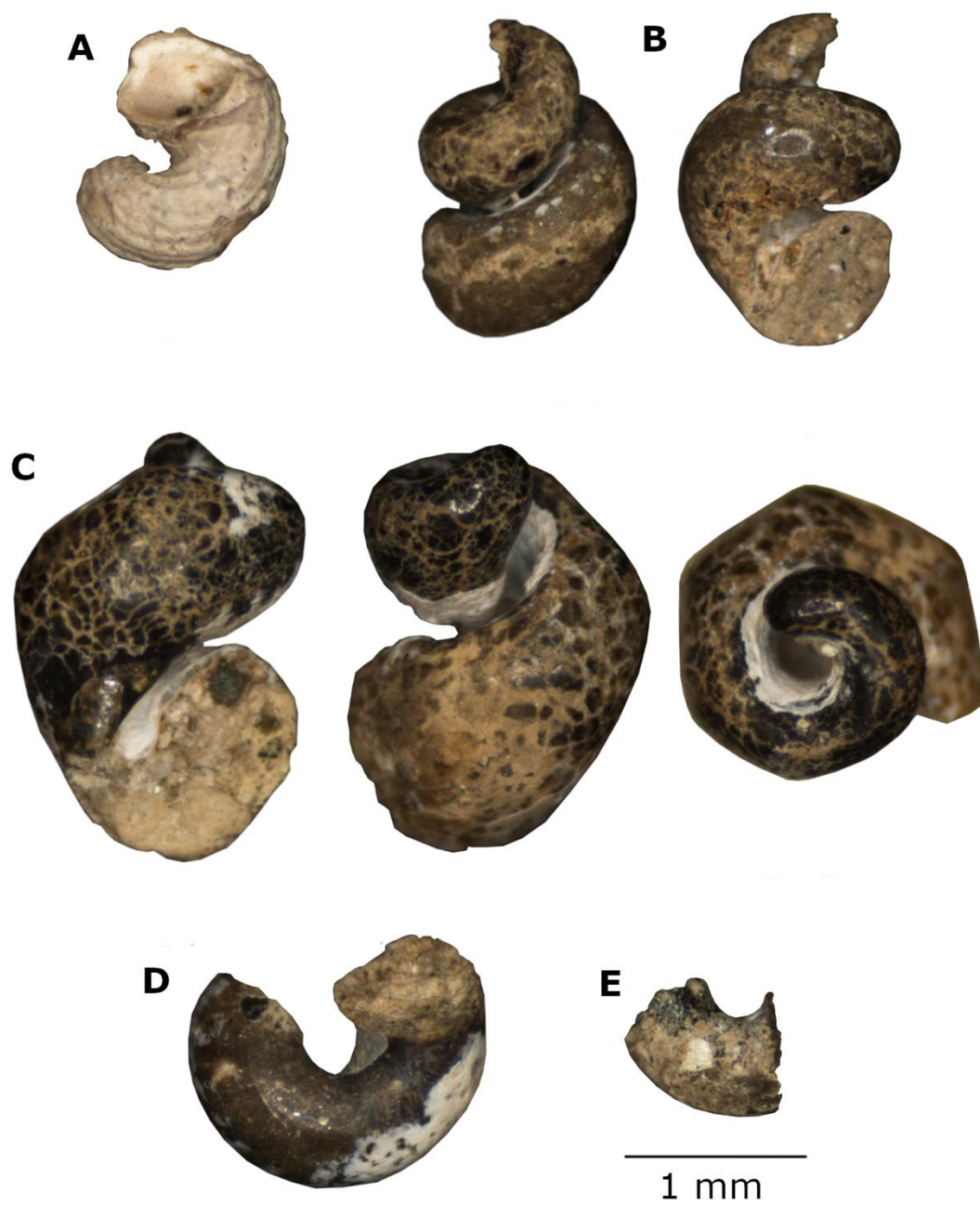


Plate 7: A) *Laxispira* cf. *lumbricalis*, fragmentary specimen. B-E) Internal molds of indeterminate gastropods.

Class SCAPHOPODA Bronn, 1862
Order GADILIDA Starobogatov, 1974
Family GADILIDAE Stoliczka, 1868
Genus CADULUS Philippi, 1844

Cadulus sp.
Plate 8: A-D

Material. 18 weathered and fragmentary shells.

Description. Specimens are elongate, tapered, slightly curved to arcuate, and smooth-shelled. Shells vary in length from 3.5 – 7 mm and in width from 0.8 – 1.6 mm.

Discussion. Compared to descriptions and images of *C. obnutus* from the Ripley Formation (Wade, 1926, p. 101; pl. XXXIII, fig. 7-8). Although the bulk sample shells are not assigned to that species due to the lack of a bulbous midsection, it is evident that they belong to *Cadulus* based on their tapered, arcuate shell morphology (Wade, 1926).

Phylum ECHINODERMATA Klein, 1754
Class ECHINOIDEA Leske, 1778
Order, Family, Gen. et sp. indet.
Plate 8: E-G

Material. 22 fragmentary regular echinoid spines.

Description. Spine fragments are thin and elongate, tapering toward the distal end. Longitudinal ribs and reduced thorns are present. Fragments are up to 9 mm in length and average around 0.8 mm in width.

Discussion. Distinguished as an indeterminate regular echinoid spine fragment on the basis that echinoderms generally have thin spines for protection and/or locomotion. The morphological characteristics of ribs, reduced thorns, and tapered shape are generally characteristic of echinoid spines (Follo and Fautin, 2001; G. Phillips, pers. comm.).

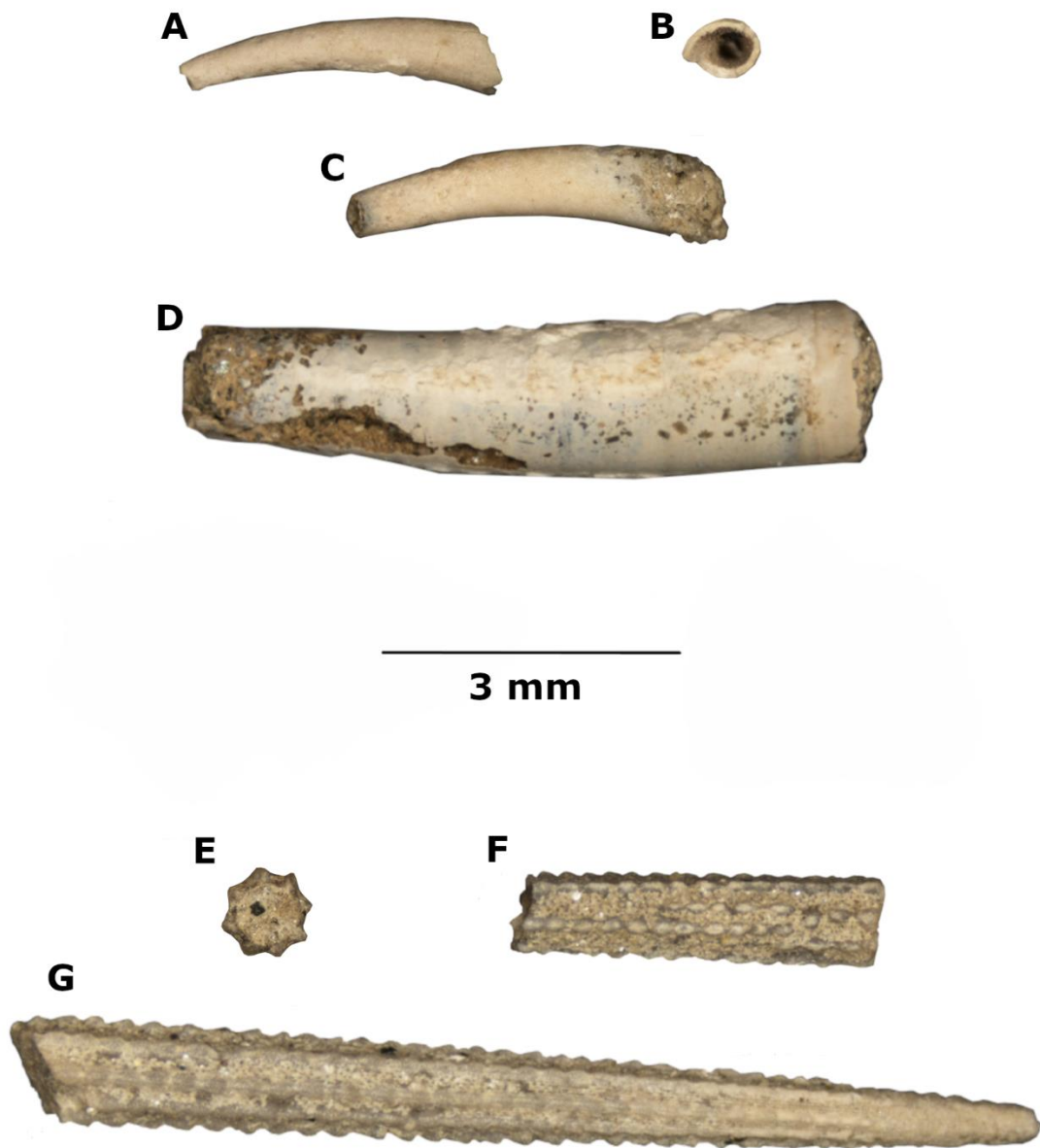


Plate 8: A-D) *Cadulus* sp. in lateral and cross-sectional views. E-G) Fragments of an indeterminate regular echinoid spine in cross-sectional and lateral views.

Phylum ANNELIDA Lamarck, 1802
Class POLYCHAETA Grube, 1850
Order SABELLIDA Levinsen, 1883
Family SERPULIDAE Rafinesque, 1815
Genus HAMULUS Morton, 1834

Hamulus onyx Morton, 1834
Plate 9: C-D

Material. 1 complete calcareous tube.

Description. The tube is tapered and consists of two visible layers: an inner, lamellar, calcareous layer and an outer, chitinous, calcareous layer (Wade, 1921). The inner layer is a smooth tube, and the outer layer has a more fibrous appearance with 6 raised longitudinal ribs along the length of the specimen from base to apex. In cross-section, the specimen has a starlike shape.

Discussion. The tube most closely compares with *H. onyx* from the Coon Creek Member (Wade, 1921; p. 43-45; pl. 9, fig. 1-3, 5, 6) and the Ripley Formation (Wade, 1926; p. 80-81; pl. 2, fig. 4-7, 12).

Hamulus squamosus Gabb, 1859
Plate 9: A-B

Material. 1 complete calcareous tube.

Description. The tube is tapered. The outer surface contains 6 axial costae with broad, winglike appendages extending from the first and fourth costae. In cross-section, the specimen appears to be a dorsoventrally compressed star with elongated horizontal medial limbs.

Discussion. This species is distinguished from *H. onyx* by the winglike appendages that extend off of the first and fourth axial costae (Wade, 1921). The cross-sectional views are also distinct for each species (Wade, 1921). This specimen compares to other specimens

of *H. squamosus* from the Coon Creek Member (Wade, 1921; p. 45-46; pl. 10, fig. 6) and the Ripley Formation (Wade, 1926; p. 81; pl. 2, fig. 4-7, 12).

Hamulus sp.
Plate 9: E-J

Material. Several hundred fragments of calcareous tubes.

Description. Fragments exhibit the same fibrous texture and similar features as *Hamulus onyx* and *Hamulus squamosus*, including raised axial costae and occasional winglike appendages. Fragmentary specimens appear much like specimens E-J on Plate 9 but are generally more fragmented.

Discussion. The fragmentary nature of the specimens prevents designation to *H. onyx* or *H. squamosus* (Wade, 1921; Wade, 1926). Characteristics are shared between those species and the fragments, but because the distinctive cross section was not preserved and cannot be observed, definitive assignment cannot be made. Wade (1921) regards *H. onyx* as one of the most common fossils in the Ripley Formation at Coon Creek, possibly explaining the abundance of fragmentary *Hamulus* sp. specimens. It is likely that numerous fragments assigned to *Hamulus* sp. are *H. squamosus*.

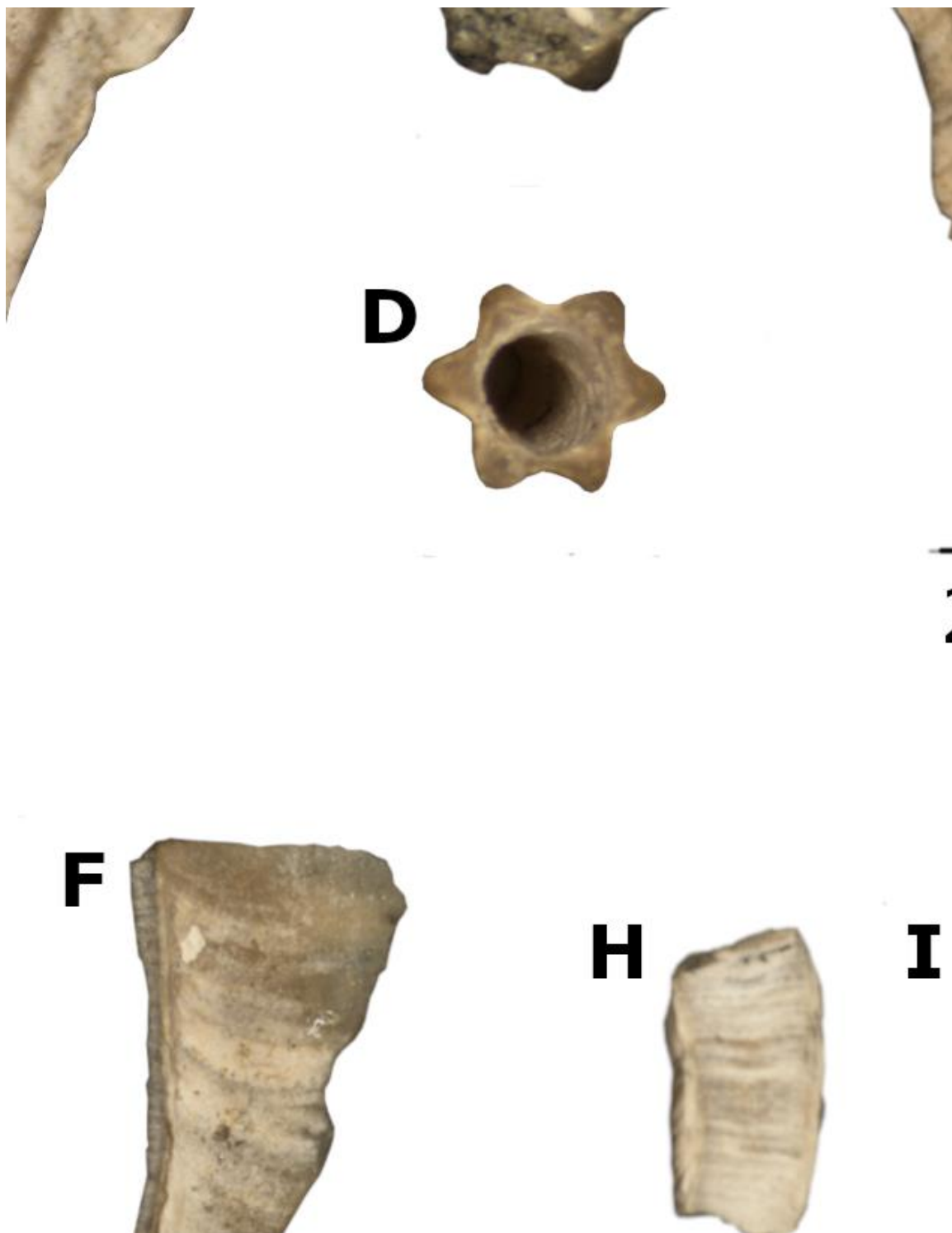


Plate 9: A-B) *Hamulus squamosus* in lateral and cross-sectional views. C-D) *Hamulus onyx* in lateral and cross-sectional views. E-G) *Hamulus* sp., exhibiting appendages similar to *H. squamosus*. H-J) *Hamulus* sp., exhibiting shape and texture similar to *H. onyx*.

Phylum ARTHROPODA von Siebold, 1848
Class OSTRACODA Latreille, 1802
Order PLATYCOPINA Sars, 1866
Family CYTHERELLIDAE Sars, 1866
Genus CYTHERELLA Jones, 1849

Cytherella tuberculifera Alexander, 1929
Plate 10: A

Material. 9 ostracod valves.

Description. Rounded, smooth-edged valves; distinguished from other observed genera by this well-rounded shape. Valve surface is punctate. Valves average 0.8 mm in diameter.

Discussion. Assigned to *C. tuberculifera* based on the rounded, oval carapace and finely punctate surfaces, as well as comparison to other Late Cretaceous specimens of *C. tuberculifera* (Puckett, 1994; fig. 4.1).

Order PODOCOPIDA Sars, 1866
Family TRACHYLEBERIDIDAE Sylvester-Bradley, 1948
Genus PTERYGOCYTHERE Hill, 1954

Pterygocythere saratogana (Israelsky, 1929)
Plate 10: B

Material. 8 specimens: 2 complete carapaces, 6 valves.

Description. Specimens subquadrate, with rounded anterior and posterior ends, a generally rounded ventral portion, and a generally straight dorsal portion. Both valves of the carapaces contain high prominent ventral alae, numerous clavate spines, and an otherwise generally smooth surface. Specimens average 1 mm in diameter.

Discussion. Assigned to *P. saratogana* based on prominent high ventral alae and close comparison to other Late Cretaceous specimens of *P. saratogana* (Crane, 1965; p. 212; pl. 4, fig. 2).

Genus BRACHYCYTHERE Alexander, 1933

Brachycythere ovata (Berry, 1925)

Plate 10: C-D

Material. 418 valves, including some complete carapaces.

Description. Subtriangular to subovate carapaces with a swollen central region on both valves. Smooth to finely punctate surfaces. Color variation is observed within the species ranging in color from tan (165 valves/carapaces) to black and white (253 valves/carapaces). Specimens average 1.1 mm in diameter.

Discussion. Distinguished by a relatively unornamented subtriangular to subovate carapace and compared to other specimens of *B. ovata* from the Ripley Formation (Crane, 1965; p. 210; pl. 4, fig. 1a-b).

Brachycythere rhomboidalis (Berry, 1925)

Plate 10: G

Material. 23 valves.

Description. Carapaces are generally subtriangular and have compressed anterior and posterior margins and few clavate spines. Valve surfaces are ornamented with coarse punctation in the central portion of the carapace. Specimens average 0.9 mm in diameter.

Discussion. Distinguished by few clavate spines and close comparison with other Ripley Formation specimens of *B. rhomboidalis* (Crane, 1965; p. 209-210; pl. 4, fig. 7).

Genus BICORNICYTHEREIS Puckett, 2009

Bicornicythereis communis (Israelsky, 1929)

Plate 10: H

Material. 1 complete carapace.

Description. Carapace generally subquadrate, with rounded anterior and posterior margins and straightened dorsal and ventral portions. Very thick carapace. Several clavate spines and no alae. Specimens average 1 mm in diameter.

Discussion. Distinguished from *Pterygocythere saratogana* in this study by the lack of alae and more straightened dorsal and ventral portions. Assigned based on very thick carapace and close comparison to other Late Cretaceous specimens of *Bicornicythereis communis* (Puckett, 2009; p. 346-348; pl. 5, fig. 1-3, 5-7, 9; pl. 6, fig. 1).

Family BAIRDIIDAE Sars, 1865
Genus BAIRDOPPILATA Coryell, Sample, and Jennings, 1935
Bairdoppilata pondera (Jennings, 1936)
Plate 10: E-F

Material. 142 specimens: mostly complete carapaces, some single valves.

Description. Robust form, larger than other ostracods in this study. Subtriangular carapace with strongly convex valves. Exhibits an adont hinge, with the groove of the right valve fitting into the ridge of the left valve, which is larger. Diameters average 1.3 mm in width.

Discussion. Distinguished from other species of ostracods based on the large size of the specimens compared to other genera, strongly convex subtriangular valves, and an adont hinge. These are most similar to other Late Cretaceous specimens of *B. pondera* (Swain, 1952; p. 71; pl. 8, fig. 8-12).

Family CYTHERIDEIDAE Sars, 1925
Genus HAPLOCYTHERIDEA Stephenson, 1936
Haplocytheridea everetti (Berry, 1925)

Material. 1 complete carapace.

Description. Small compared to other ostracods in this study. Carapace is elongate, tapering towards the posterior margin. Surface is lightly punctate.

Discussion. The elongated, tapered anterior end of the carapace is distinctive of the species (Puckett, 1992) and is consistent with other Cretaceous specimens of *H. everetti* (Puckett, 1992; pl. 2, fig. 14).

Class MALACOSTRACA Latreille, 1802
Order DECAPODA Latreille, 1802

Family, Gen. et sp. indet.

Material. Several hundred small decapod carapace fragments.

Description. Abundant dark brown to black decapod carapace fragments range in size from less than 1 mm – 3 mm. Some fragments were ornamented with small tubercles, others were patterned with irregular lines.

Discussion. The dark color and knobby texture of the fragments indicated decapod origin. Several decapod species have been recorded at the Blue Springs site (Bishop, 1983), including *Dakoticancer australis* Rathbun, 1935 and *Avitelmessus grapsoides* Rathbun, 1923, which were collected as incidentals in this study. It is possible that these fragmentary specimens belong to one of the previously mentioned species, but they were not assigned or imaged due to their fragmentary nature.

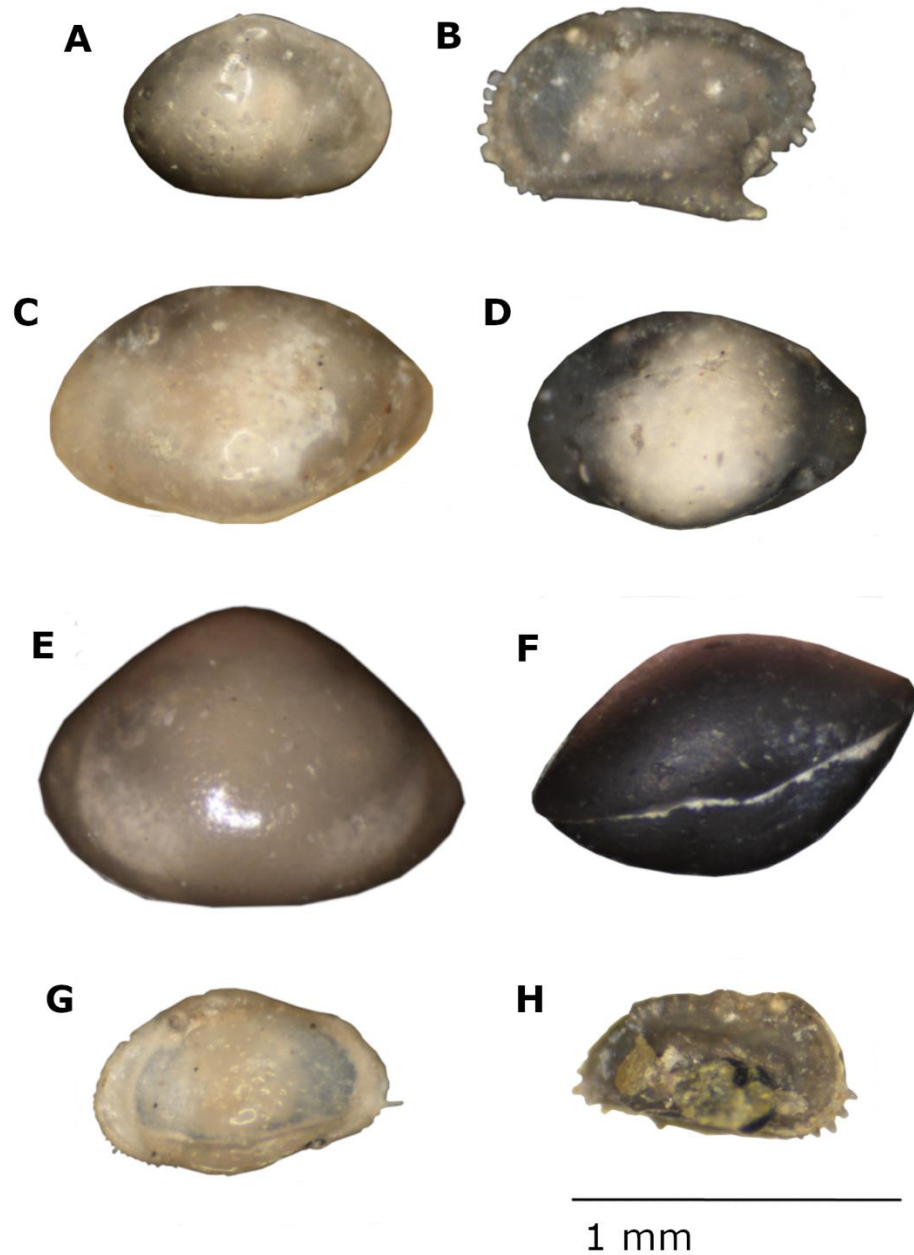


Plate 10: A) *Cytherella tuberculifera*, exterior. B) *Pterygocythere saratogana*, exterior. C-D) *Brachycythere ovata*, exterior views, exhibiting color variation within the species. E-F) *Bairdoppilata pondera*, exterior and dorsal view, exhibiting an adont hinge. G) *Brachycythere rhomboidalis*, exterior. H) *Bicornicythereis communis*, exterior.

Phylum CHORDATA Haeckel, 1874
Class ACTINOPTERI Cope, 1871
Order, Family, Gen. et sp. indet.
Plate 11

Material. 18 otolith fragments.

Description. All 18 fragmentary otoliths were weathered and broken, missing most of the original material necessary for identification.

Discussion. Because otoliths occur in bony fishes, these specimens were assigned to class Actinopteri but could not be further assigned due to their fragmentary state.

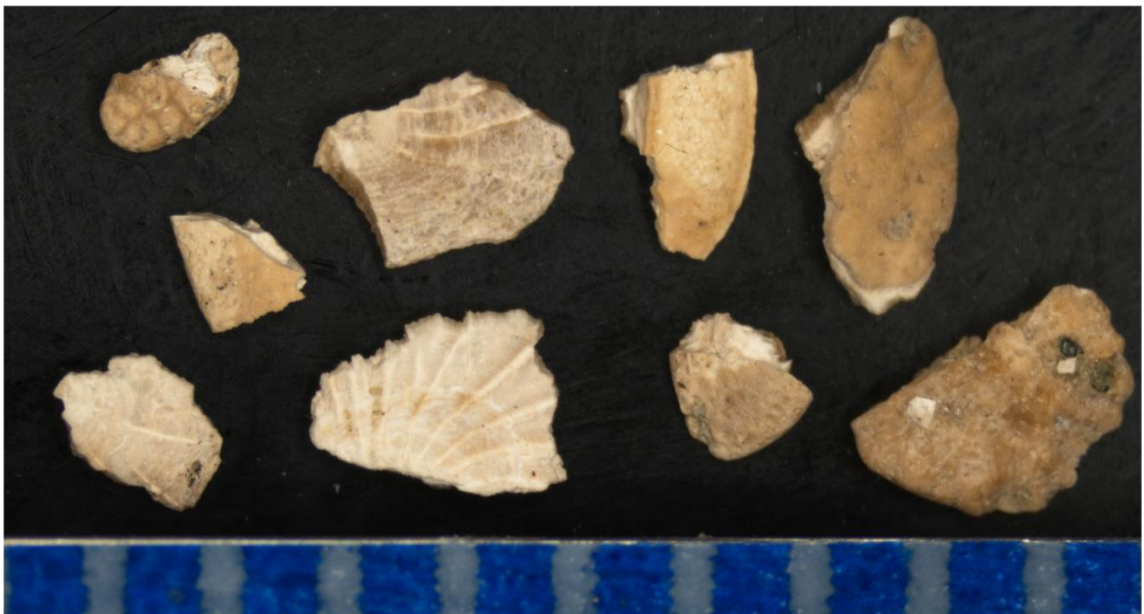


Plate 11: Half of the unidentifiable otolith fragments.

Subclass TELEOSTEI
Order, Family, Gen. et sp. indet.
Plate 12

Material. 47 complete vertebrae.

Description. Of all of the fish vertebrae observed in the sample, 17 representative specimens were imaged to illustrate variation in general shape and size. Specimens FV1, FV2, FV5, and FV6 resemble each other; their composition is delicate, light brown, translucent material. These vertebrae are elongate and range in length from 1.0 – 1.8 mm and average about 0.6 mm in width in the narrow median portion. FV3 is generally more robust than the other specimens and is composed of brown material that is thicker, more durable, and more complex. The shape is stout, with a width of 1.0 mm and a length of 1.6 mm. FV4 has a brown, thick, durable composition similar to FV3, but one end of the vertebrae is wider than the other (1.4 mm – 1.0 mm). Approximately 30 other fish vertebrae composed of the light brown, translucent material were observed in the smallest sieve size concentrate.

Discussion. Based on the general shape and ornamentation, the vertebrae most closely resemble teleost vertebrae (Sakashita et al., 2019; fig. 1-2).

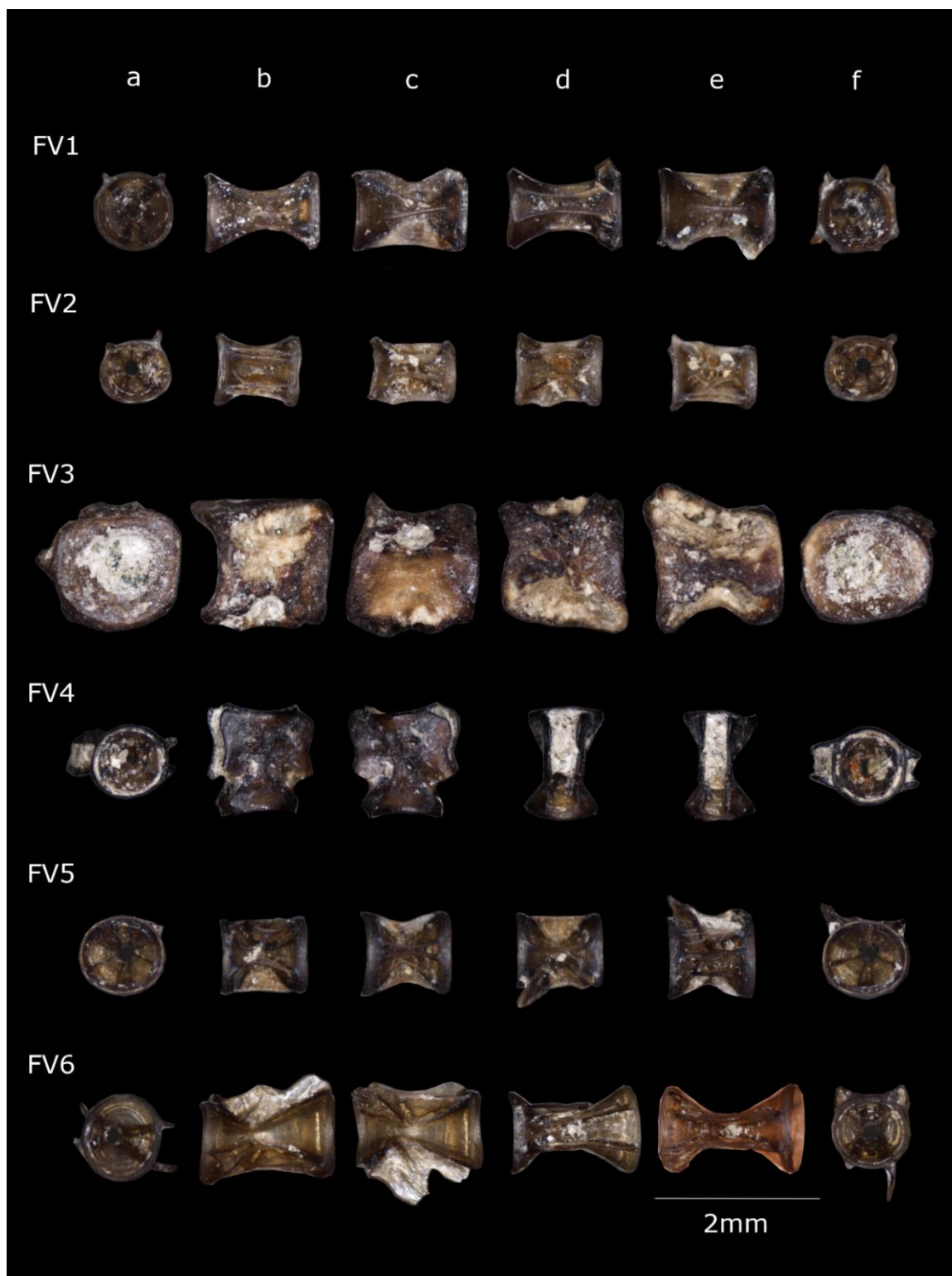


Plate 12: Teleost vertebrae were imaged to document size, overall shape, and accessory features.

Class ACTINOPTERI Cope, 1871
Order ANGUILLIFORMES Regan, 1909
Family indet.
Genus MURAENANGUILLA Schwarzhans, 2019
Muraenanguilla unionensis Schwarzhans & Stringer, 2020
Plate 13: A-E

Material. 5 otoliths (inner ear bones): 4 complete otoliths, 1 fragmentary otolith.

Description. Although heavily weathered, the distinguishing details of the specimens are visible: an oval outline, an undivided and inclined sulcus, and a median rostrum and posterior tip. These otoliths are 2 mm in width.

Discussion. These specimens are assigned to the anguilliforms, “true eels,” because of their undivided sulcus and oval shape and assigned to *Muraenanguilla unionensis* because the sulcus is inclined (Stringer et al., 2020). These specimens are most similar to another specimen of *M. unionensis* from Blue Springs (Stringer et al., 2020; Fig. 5 F-L).

Class CHONDRICHTHYES Huxley, 1880
Order HYBODONTIFORMES Patterson, 1966
Family LONCHIDIIDAE Herman, 1977
Genus LONCHIDION Estes, 1964

Lonchidion sp.
Plate 13: F

Material. 8 fin spines.

Description. Fin spines of these shark-like hybodonts are elongate and taper distally. Some specimens (not imaged) have a prominent articulation point on the proximal end and taper distally to a fine, thin point. Others (Plate 13, Figure F) taper distally, but they are more robust and have a longitudinal median furrow and lateral ridges on one side.

Discussion. The fin spines most closely resemble the dorsal fin spine fragments of *Lonchidion* from the Late Cretaceous (Kirkland et al., 2013; p. 161, fig. 9.6 V) with similar lateral ridges along one side.

Order LAMNIFORMES Berg, 1958
Family OTODONTIDAE Gluckman, 1964
Genus CRETOLAMNA Glikman, 1958

cf. *Cretolamna* sp.
Plate 14: A-B

Material. 1 weathered tooth.

Description. The single tooth is weathered and is 3.5 mm in width. Three cusplets are visible but no crown, indicating that this specimen is incomplete. The cusplets are broad and triangular, and the largest cusp is very slightly recurved.

Discussion. Due to the very small size and incomplete nature of the tooth, it cannot be definitively assigned to a genus or species. However, the tooth has been provisionally assigned to *Cretolamna* based on the triangular shape of the visible cusplets (Case and Schwimmer, 1988).

Class REPTILIA Laurenti, 1768
Order SQUAMATA Oppel, 1811
Family MOSASAURIDAE Gervais, 1852

Mosasauridae
Plate 14: C-F

Material. 1 mosasaurid tooth.

Description. The tooth is heavily weathered, but longitudinal striations are visible on sections where the enamel is still present. General shape is resemblant of a mosasaur

tooth with a very slight recurve, although the specimen is very small (3.5 mm long and 1.5 mm wide).

Discussion. The tooth closely resembles a mosasaur tooth (Dockery, 1992; pl. 2, fig 1a and 4b), but because of the very small size, identification is uncertain. The tooth is provisionally assigned to Mosasauridae.

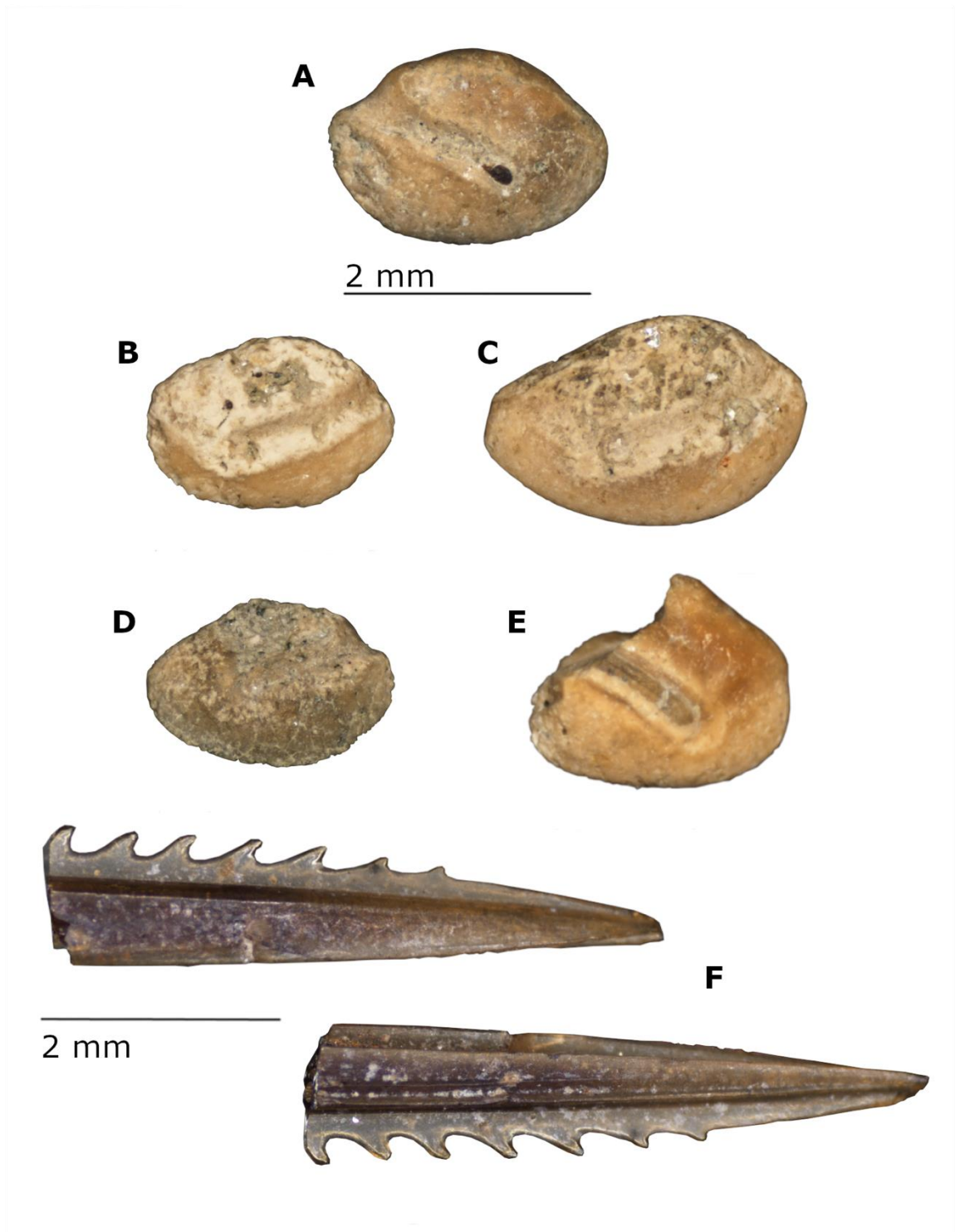


Plate 13: A-E) Weathered specimens of *Muraenanguilla unionensis*. F) A *Lonchidion* fin spine in both lateral views.

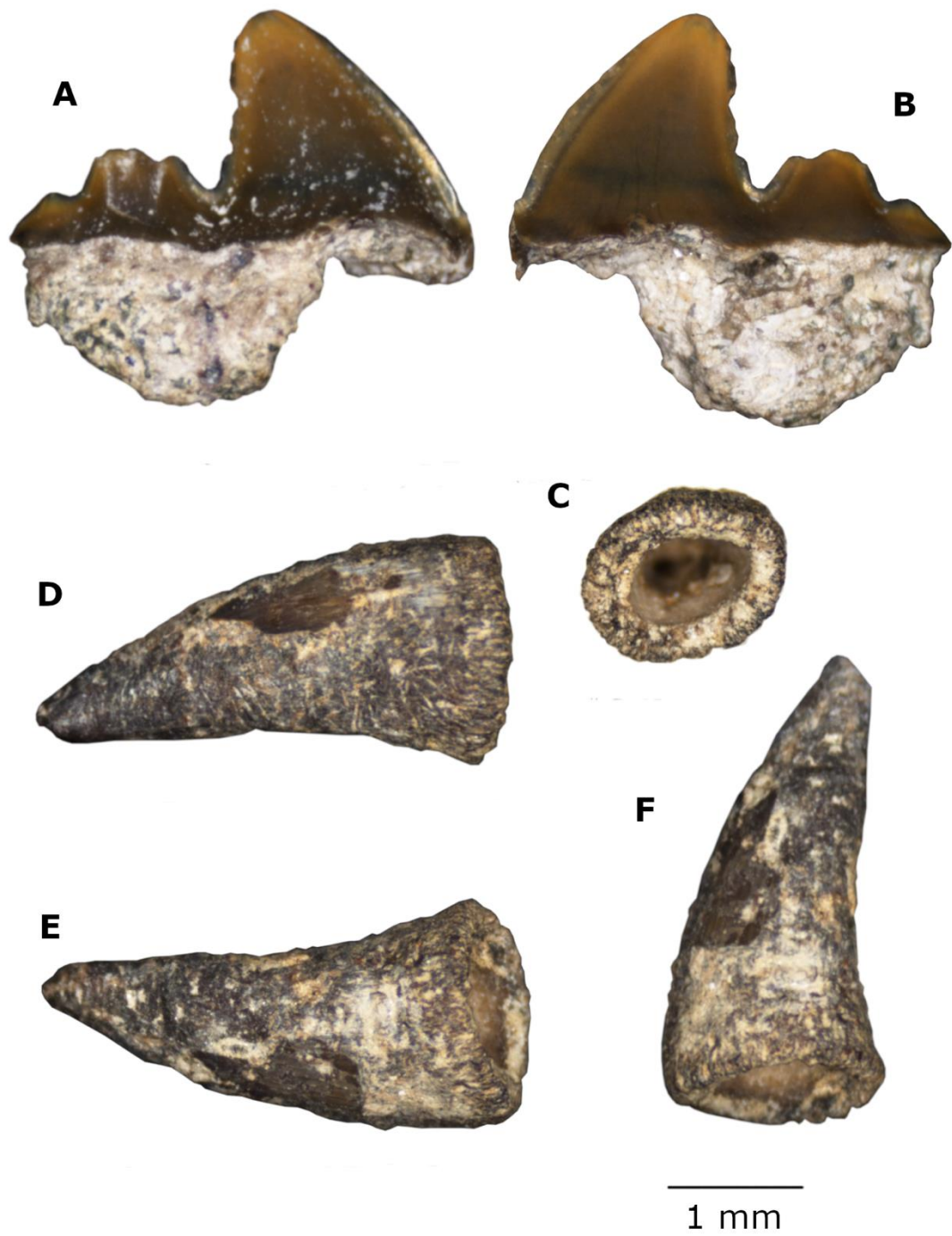


Plate 14: A-B) Shark tooth provisionally conferred to *Cretolamna*, buccal and lingual views. C-F) Provisionally assigned mosasaurid tooth in multiple views.

CHAPTER V: RESULTS

Of the 59.4 g of concentrate resulting from processing Bed J, 33.4 g were picked for fossils (Plates 1 – 14). Bed G and the concentrate from Bed C were not fully processed or picked. The bulk sample Bed J concentrate was the only material completely processed for fossils; those fossils were the only material considered for abundance data, and clear paleoenvironmental interpretations were only made for this bed. However, all of the specimens from each bed in the Results section are included in the faunal list (Appendix A).

Because the Blue Springs site was still submerged by the Western Interior Seaway during the Maastrichtian, all of the recovered fossil material is of marine origin. The concentrate from Bed J yielded a total of 3,088 specimens representing at least 37 species from 12 different taxonomic groups of organisms (Table 1), as well as some lignitized wood, oxidized aggregates, and abundant mica. The total number of fossil specimens was determined by counting the specimens (complete and fragmentary) after they were assigned to a species. Minimum number of represented species was determined by counting the definitively assigned taxa, as well as conferred taxa and taxa that could not be identified but distinctly represented a separate species. It should be noted that the total number of specimens recorded for polychaetes (*Hamulus onyx*, *H. squamosus*, and *H. sp.* undifferentiated) and teleost fish (vertebrae) are estimates, but true values are no less than those listed in the table.

Table 1: Number of species and representative specimens of each group of observed organisms in the concentrate from Bed J.

Type of Organism	Minimum Number of Species Represented	Total Number of Specimens Recorded
Foraminifera	14	1,835
Ostracods	7	608
Polychaetes	2	500
Teleost Fish (vertebrae)	1	47
Bony Fish (otoliths)	1	18
Echinoids	1	22
Scaphopods	1	18
Bivalves	1	14
Gastropods	2/5*	11
Anguilliforms (otoliths)	1	5
Chondrichthyans (tooth and fin spines)	2	9
Mosasaurs	1	1
Total:	37	3,088

*Two species of gastropods were definitively assigned, but there are a minimum of five possible species represented by the eleven individual complete and fragmentary specimens.

Foraminifera comprise the greatest percentage of recorded specimens from Bed J bulk in both number of species (34.15% of the observed species) and number of specimens (59.42% of the sample). Ostracods follow foraminifera in relative abundance and speciation. Next, polychaetes are substantially more abundant than all other invertebrate and vertebrate organisms, but are represented by only two species. Other invertebrates, including the echinoids, scaphopods, and bivalves, each represent a minimum of one species and do not exceed a total of 22 specimens per group. Gastropods (definitively assigned and interpreted distinct species) represent a minimum of five species with 11 specimens. The teleost fish and bony fish each represent at least one species, with 47 and 25 specimens, respectively. The five anguilliform specimens only represent one species. Mosasaurs and chondrichthyans (*Cretolamna* sp. and *Lonchidion* sp.) are minimally represented in the sample by single teeth or few fin spines. With the

exception of the polychaete calcareous tubes, the molluscs, gastropods, other invertebrates, and vertebrate organisms are minimally represented in comparison to the microfossils, which dominate Bed J.

In addition to fossils picked from the concentrate, incidental specimens from Bed J (Table 2) were collected adjacent to the bulk sample location. These fossils occur as complete specimens, with the exception of the sea pen fragments and the decapods. While the recovered carapaces of crabs *Dakoticancer australis* and *Avitelmessus grapsoides* are mostly complete, the claws and some leg segments occur in greater abundance.

Table 2: Incidental specimens collected from Bed J.

Group of Organism	Name	Reference Used for Specimen Identification
Bryozoans	Unidentified branching forms	(Wade, 1926)
Bivalves	<i>Exogyra costata</i>	(Wade, 1926; pl. XV, fig. 1-2)
	<i>Pycnodonte mutabilis</i>	(Dockery, 2020; p. 70)
Sea pens	Unidentified fragments	
Nautiloids	<i>Eutrophoceras planoventer</i>	(Bandel and Dockery, 2016)
Decapods	<i>Dakoticancer australis</i> appendages	(Bishop, 1983)
	<i>Avitelmessus grapsoides</i> appendages	(Bishop, 2016) (Thompson and Dockery, 2016; p. 226, fig. 289)
Sharks	Unidentified shark tooth type 1	(Dockery, 1992)
	Unidentified shark tooth type 2	(Dockery, 1992)
	Unidentified shark tooth type 3	(Dockery, 1992)
	Unidentified shark vertebra	(Dockery, 1992)

Although the processed concentrate from Bed C was not analyzed, some visible, delicate specimens were extracted from the sieves to prevent breakage (Table 3). The fossils are primarily micromolluscs, very small gastropods and bivalves. Incidentals

collected from this layer (Table 4) represent a variety of molluscs, but decapods and vertebrates are also noted.

Table 3: Bulk specimens from Bed C removed from the concentrate during sieving to protect the specimens from damage.

Group of Organism	Name	Reference for Identification
Bivalves	<i>Anomia argentaria</i>	(Dockery, 2020; p. 87)
	<i>Corbula crassiplica</i>	(Wade, 1926)
	<i>Cardium dumosum</i>	(Wade, 1926)
Gastropods	<i>Turritella tippiana</i>	(Dockery, 1993)
	<i>Turritella triliria</i>	(Dockery, 1993)
	<i>Turritella vertebroides</i>	(Dockery, 1993)
	<i>Mesostoma costatum</i>	(Wade, 1926)
	<i>Polinices</i> sp.	(Wade, 1926)
Nautiloids	<i>Eutrephoceras dekayi</i>	(Wade, 1926)
Solitary Coral	<i>Micrabacia</i> sp.	(Wade, 1926)
Actinopterygians (otoliths)	<i>Hoplopteryx langfordi</i>	(Stringer et al., 2020)

Table 4: Incidental specimens collected from Bed C.

Group of Organism	Name	Reference for Identification
Bivalves	<i>Crassatella</i> sp.	(Dockery, 2020)
	<i>Corbula crassiplica</i>	(Wade, 1926)
	<i>Trigonia thoracica</i>	(Wade, 1926; pl. 10, fig. 1-2)
	<i>Cardium dumosum</i>	(Wade, 1926)
Gastropods	<i>Turritella vertebroides</i>	(Dockery, 1993)
	<i>Polinices</i> sp.	(Wade, 1926)
	<i>Volutomorpha valida</i>	(Thompson and Dockery, 2016; p. 226, fig. 291)
Scaphopods	<i>Cadulus</i> sp.	(Wade, 1926)
Nautiloids	<i>Eutrephoceras planoventer</i> with visible siphuncle	(Bandel and Dockery, 2016)
Decapods	<i>Dakoticancer australis</i> claws	(Bishop, 1983)
Actinopterygians (otoliths)	<i>Arius subtilis</i>	(Stringer et al., 2020)
	<i>Eutawichthys maastrichtiensis</i>	(Stringer et al., 2020)
	<i>Hoplopteryx langfordi</i>	(Stringer et al., 2020)
	<i>Hoplopteryx oscitans</i>	(Stringer et al., 2020)
Sharks	Unidentified shark tooth	(Dockery, 1992)
	Unidentified shark vertebra	(Dockery, 1992)

The nodules and concentrate from Bed G were not processed, but an approximately 6 cm wide external mold of *Trigonia thoracica* is visible in the side of one of the large blocks (Figure 18).

CHAPTER VI: DISCUSSION

Discussion of Results

Foraminifera dominate Bed J. This could be partly due to their small size, but they are also easily preserved as a result of their benthic mode of life. Benthic foraminifera dwell on the seafloor, either attached or free-floating near the basal sediment. Their proximity to the sediment makes burial after death very likely, increasing preservation potential and fossilization. Other organisms may not have been as abundantly preserved for similar reasons. Sharks and mosasaurs are minimally represented in the sample, indicating that sharks and mosasaurs, at least of a small body size, were not abundant in Bed J. These organisms are generally larger, and they are also pelagic, free-swimming, active predators that travel wide ranges, not benthic dwellers such as foraminifera.

In Beds J and C, the legs and claws of decapods were preserved in greater abundance than carapaces. Decapod appendages are generally more heavily mineralized, resulting in greater thickness than the thinner, delicate carapaces. The legs and claws are therefore sturdier and resistant to breakage, thus they are preferentially preserved and appear more numerous in the fossil record (Bishop, 1983). In addition, decapods generally have 10 legs and a single carapace, resulting in a statistical advantage due simply to body plan.

Evidence for Paleoenvironmental Differences Between Beds

Molluscs are minimally represented in Bed J. Although Bed C was not fully processed, the fauna collected in the field and in sieving reveal that these organisms dominate Bed C. Most gastropods and bivalves are benthic, so preservation potential is increased similarly to that of foraminifera. However, preservation may differ based on

environment as a result of shell composition, with aragonitic shells being less likely to be preserved in more acidic environments, for example. To fully understand the difference in abundance of molluscs in each bed, specifically the much greater abundance of micromolluscs in Bed C, further analysis must be conducted. Paleoenvironmental differences cannot be defined without more research, but the differences in faunal assemblages and relative abundance indicate changes in paleoenvironmental conditions. Paleoenvironmental conditions may include changes in temperature, salinity, weather patterns, or sea level, all of which will be better understood with future analysis of the beds.

Further evidence for changes in paleoenvironment includes the lag deposit (Bed G) left behind in a period of erosion some time between the deposition of Beds C and J (Bishop, 1983). This erosional surface was not observed in the outcrop, but if the nodules of Bed G were deposited as lag from a period of erosion, that would indicate that sea level was low enough for erosion to occur before rising again, allowing the deposition of the layers above Bed G. The Blue Springs site documents some of the final incursions of the Western Interior Seaway; the shorelines and sea level of the seaway fluctuated over time and ultimately retreated in the late Maastrichtian, so changes in sea level could have periodically affected the environment of Bed J (Roberts and Kirschbaum, 1995). Further analysis is necessary to describe the different faunal assemblages of each bed in detail to determine paleoenvironmental changes during the interval in which the beds were deposited. Nevertheless, the current data support differences between the beds.

Paleobathymetry and Paleoenvironment

The diversity of foraminifera and ostracods observed in Bed J provides some of the most useful information for interpreting paleoenvironmental conditions, including depth and salinity levels. Based on morphological features (generally flattened and internally complex tests), 100% of the observed foraminifera from Bed J are benthic foraminifera rather than planktonic. Benthic organisms live on the seafloor, either attached or free-floating, whereas planktonic organisms live suspended in the pelagic zone (Brasier, 1980). Because the percentage of benthic foraminifera decreases with water depth and 100% of the Bed J foraminifera are benthic, there is strong evidence that the paleoenvironment at Blue Springs was restricted to the shelf/neritic zone, the upper 200 m of the ocean (Figure 27). The maximum diversity of benthic foraminifera occurs in the deepest portion of the neritic zone near 200 m (Brasier, 1980). The relatively low foraminifera diversity in Bed J suggests that the depth was further restricted to a shallower area, likely to the inner to middle neritic zone between 0 and 100 m.

Ostracod data was used in conjunction with foraminifera data to further constrain the paleobathymetry. Puckett (1992) illustrates the depth ranges of various ostracods during the middle Maastrichtian (Figure 28). Of those observed in this study, *Pterygocythere saratogana* and multiple species of *Bairdoppilata* were recorded by Puckett to occur minimally (1-10 specimens) throughout the entire neritic zone (Puckett, 1992). *Haplocytheridea everetti* and *Brachycythere rhomboidalis* also occurred throughout the neritic zone, slightly more abundantly (11-50 specimens in each section of the neritic zone). Multiple species of *Cytherella* were recorded in the inner to middle neritic zone (51-100 specimens) and more abundantly in the middle to outer neritic zone

(101-200 specimens). Finally, *Brachycythere ovata* was recorded in the middle to outer neritic zone (11-50 specimens) and much more abundantly in the inner to middle neritic zone (101-200 specimens). Six of the seven observed ostracods are recorded in this depth chart, with the exception of *Bicornicythereis communis*, of which only one specimen was recorded. The six ostracod species overlap in depth recording, but the most abundant species was *Brachycythere ovata*, comprising 69% of the recorded ostracod specimens. The higher abundance of *B. ovata* suggests that the paleobathymetry at the time the Bed J faunal assemblage was thriving was no deeper than 100 m in the inner to middle neritic zone.

Foraminifera test composition can indicate another important paleoenvironmental condition, salinity (Figure 27). Freshwater foraminifera are distinguished by organic-walled tests, while marine foraminifera are generally assigned to one of three groups based on test composition: miliolids, textulariids, and rotaliids (Brasier, 1980). Miliolids have a calcareous, porcelaneous composition and appearance. Textulariids have agglutinated tests composed of collected particles cemented together by organic secretions or calcareous cement to form tests. Rotaliids generally have multichambered hyaline calcite tests and exhibit planispiral, trochospiral, or serial growth. There are only rotaliid foraminifera in Bed J, indicating normal marine salinity comparable to most shelf seas, which is generally 35 parts per thousand (ppt).

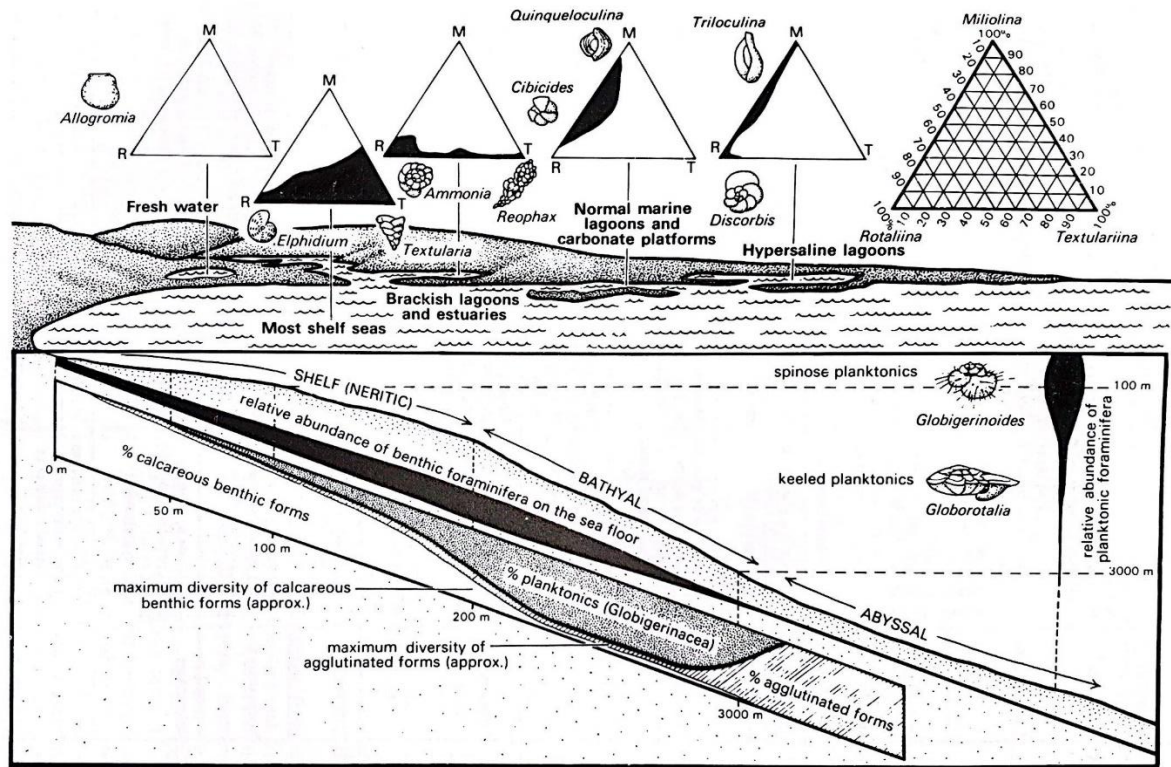


Figure 27: Illustration of changes in abundance of benthic and planktonic foraminifera as well as miliolid, textulariid, and rotaliid types with changes in depth and salinity (Brasier, 1980).

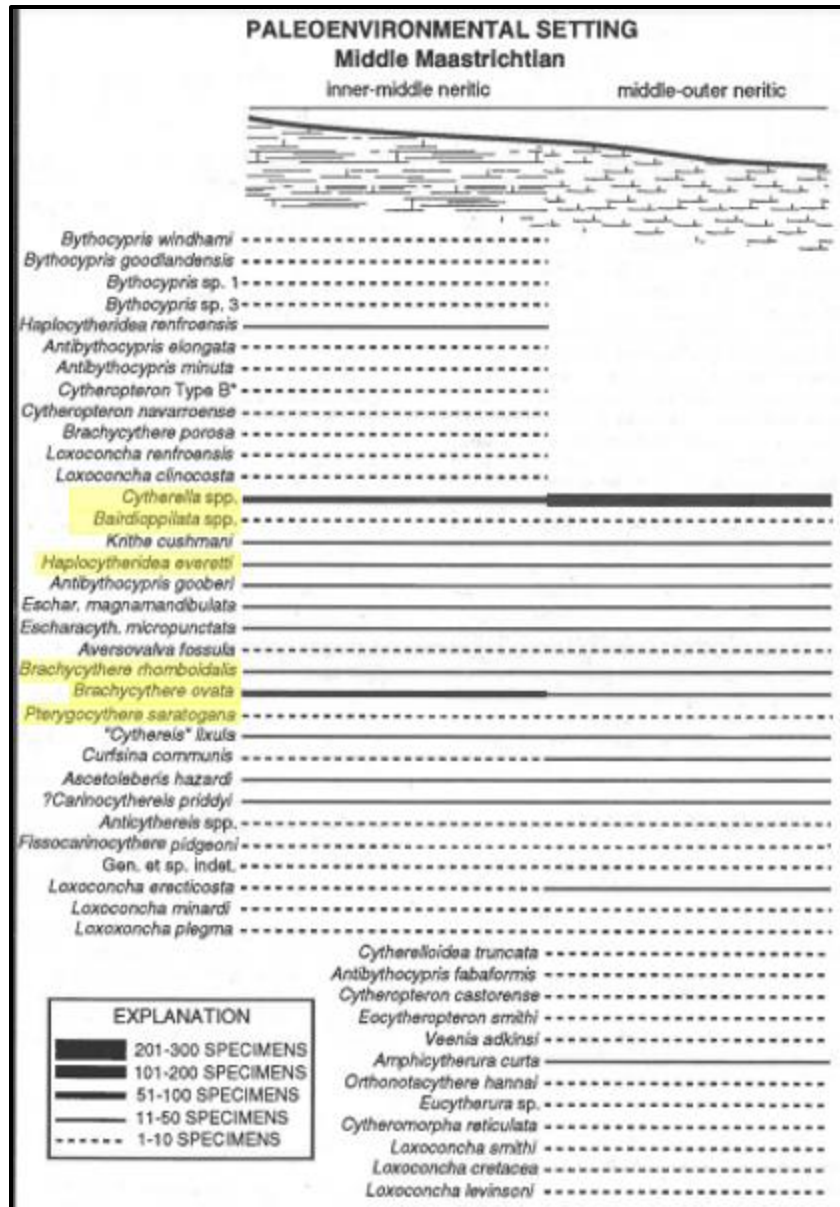


Figure 28: Ostracod depth distribution from the middle Maastrichtian (Puckett, 1992). Highlighted taxa are those that were present in the Bed J concentrate.

In addition to fossils, some lignitized wood, oxidized aggregates, and abundant mica were present in the sample. The inclusion of wood may indicate a nearshore environment, and the oxidized aggregates suggest periods of exposure to air, perhaps as a result of sea level changes. The sediment from the site is best described as highly

fossiliferous, gray to green, micaceous, clay-rich sand, sediment types which can occur in marine settings. The abundance of clay in Bed J presented challenges with sediment disaggregation when sieving; however, the aggregating properties and impermeable nature of clay may have formed a barrier between the decaying organic material and the external processes that usually disrupt or prevent fossilization: oxygen, bacteria, scavenging, etc. This may have contributed to the excellent preservation of the diverse faunal assemblage in Bed J.

The presence of marine fossils, the microfossil data, and the sediment composition indicate that in the Maastrichtian, Bed J of the Blue Springs site was a shallow normal marine salinity environment that could support a variety of species. Because the southeastern United States was a tropical environment at that time and there has been no evidence of glaciation or freezing temperatures, the site also had moderate temperatures that allowed species to flourish (Roberts and Kirschbaum, 1995).

Future Research

To assess changes in paleoenvironmental conditions and causes for such changes, further analysis is necessary. This preliminary work establishes that the beds at Blue Springs contain very different faunal assemblages, and with more analysis of the fossil content from each bed, paleoenvironmental changes can be interpreted with a more detailed comparison.

CHAPTER VII: CONCLUSIONS

The Blue Springs site preserves several genera of marine organisms as a result of the site being submerged by the Western Interior Seaway during the time of deposition 71 million years ago. Based on the material picked during the project period, the fossils from Blue Springs are very well preserved, possibly due to the clay content in the sediment. The concentrate from Bed J yielded 3,088 specimens, representing a diverse faunal assemblage. Remaining picked sediment and minerals confirm that the site consists of fossiliferous, green-gray, glauconitic, micaceous clay-rich sand, as described by Bishop (1983). Data from the foraminifera and ostracod assemblages were used to determine paleobathymetry and paleoenvironment, supporting that Bed J at the Blue Springs site was a shallow marine, near shore environment with normal salinities and moderate temperatures that could support a variety of life, including microfossils, as well as invertebrate and vertebrate macrofossils.

The fossils from the concentrate of Bed J, incidental specimens from Beds J, C, and G, and some of the concentrate from Bed C have been combined with published lists of fauna from Blue Springs. The results of this study and published works document at least 140 species present at the Blue Springs site (Appendix A).

Present data is foundational for future study of variation in the faunal assemblages of each bed at the Blue Springs site to assess changes in paleoenvironmental conditions throughout deposition. It is possible that other fossils that were not observed in the picked material or incidentals are present at the Blue Springs site, yet not accounted for in this faunal list. As researchers continue to study this site, new taxa will be added to the list.

APPENDIX A: FOSSIL FAUNAL COMPOSITION LIST

Table A1: Fossil Faunal Composition List of the Maastrichtian Age Blue Springs Site in Northeastern Mississippi.

Specimens	References
Foraminifera:	(Cushman, 1946)
<i>Fronicularia frankei</i>	
<i>Nodosaria affinis</i>	
<i>Robulus</i> sp.	
<i>Robulus stephensoni</i>	
<i>Robulus münsteri</i>	
<i>Robulus spissocostatus</i>	
<i>Robulus pondi</i>	
<i>Vaginulina</i> sp.	
<i>Vaginulina webbervillensis</i>	
<i>Vaginulina taylorana</i>	
<i>Vaginulina wadei</i>	
<i>Pseudopolymorphina cuyleri</i>	
<i>Bullopore laevis</i>	
<i>Cibicides harperi</i>	
Bivalvia:	(Dockery, 2020; Wade, 1926)
<i>Anomia argentaria</i>	
<i>Exogyra costata</i>	
<i>Pycnodonte mutabilis</i>	
<i>Corbula crassiplica</i>	
<i>Cardium dumosum</i>	
<i>Crassatella</i> sp.	
<i>Trigonia thoracica</i>	
Gastropoda:	(Dockery, 1993; Wade, 1926)
<i>Turritella trilira</i>	
<i>Turritella vertebroides</i>	
<i>Turritella tippiana</i>	
<i>Laxispira lumbricalis</i>	
<i>Mesostoma costatum</i>	
<i>Polinices</i> sp.	
<i>Volutomorpha valida</i>	
<i>Anchura</i> sp.	
Sea pens:	
Unidentified fragments	

Scaphopoda:	(Wade, 1926)
<i>Cadulus</i> sp.	
Echinoidea:	(Wade, 1926; G. Phillips, pers. comm.)
Indet. Regular Echinoid	
Solitary Coral:	(Wade, 1926)
<i>Micrabacia</i> sp.	
Cephalopoda:	(Bishop, 2016)
<i>Sphenodiscus</i> sp.	
Nautiloidea:	(Wade, 1926; Bandel and Dockery, 2016)
<i>Eutrephoceras dekayi</i>	
<i>Eutrephoceras planoventer</i>	
Bryozoans:	(Wade, 1926)
Indet. branching forms	
Polychaeta:	(Wade, 1921; Wade, 1926)
<i>Hamulus onyx</i>	
<i>Hamulus squamosus</i>	
Ostracoda:	Unpublished data from T.M. Puckett
<i>Acuminobrachycythere foraminosa</i>	
<i>Acuminobrachycythere ledaforma</i>	
<i>Ayselgulina forresterae</i>	
<i>Ayselgulina verricula</i>	
<i>Amphicytherura pandicosta</i>	
<i>Antibythocypris cavernosa</i>	
<i>Antibythocypris crassa</i>	
<i>Antibythocypris elongata</i>	
<i>Antibythocypris fabaformis</i>	
<i>Antibythocypris gooberi</i>	
<i>Antibythocypris macropora</i>	
<i>Antibythocypris phaseolites</i>	
<i>Anticythereis slipperi</i>	

<i>Ascetoleberis hazzardi</i>	
<i>Bairdoppilata</i> spp.	
<i>Bairdoppilata pondera</i>	
<i>Bicornicythereis communis</i>	
<i>Brachycythere ovata</i>	
<i>Brachycythere rhomboidalis</i>	
<i>Cytherella tuberculifera</i>	
<i>Cytherelloidea crafti</i>	
<i>Cytherelloidea tollettensis</i>	
<i>Cytheropteron navarrense</i>	
<i>Cushmanidea</i> sp.	
<i>Escharacytheridea magnamandibulata</i>	
<i>Escharacytheridea micropunctata</i>	
<i>Escharacytheridea pinochii</i>	
<i>Eucythere sohli</i>	
<i>Fissocarinocythere huntensis</i>	
<i>Fissocarinocythere pidgeoni</i>	
<i>Floricythereis lixula</i>	
<i>Frodocythereis</i> sp. 1	
<i>Haplocytheridea bruceclarki</i>	
<i>Haplocytheridea everetti</i>	
<i>Haplocytheridea renfroensis renfroensis</i>	
<i>Krithe cushmani</i>	
<i>Laevipellacythereis</i> sp. 1	
<i>Loxoconcha</i> spp.	
<i>Paracypris</i> spp.	
<i>Pterygocythereis (Pterygocythere) saratogana</i>	
<i>Tumulocythereis incompta</i>	
<i>Tumulocythereis</i> sp. 1	
<i>Tumulocythereis tiberti</i>	
<i>Veenia arachoides</i>	
<i>Xestoleberis opina</i>	
Decapoda:	(Bishop, 1983; Bishop, 2016)
<i>Paguristes whitteni</i>	
<i>Dakoticancer australis</i>	
<i>Avitelmessus grapsoideus</i>	
<i>Cristipluma mississippiensis</i>	

<i>Linuparus canadensis</i>	
<i>Hoploparia tennesseeensis</i>	
<i>"Eryma" flecta</i>	
<i>Protocallianassa mortoni</i>	
<i>Tetracarcinus subquadratus</i>	
<i>Raninella tridens</i>	
<i>Notopocorystes testacea</i>	
<i>Palaeopagurus whitteni</i>	
<i>Seorsus wadei</i>	
<i>Prehepatus harrisi</i>	
Actinopteri:	(Stringer et al., 2020)
<i>Enchodus</i> sp.	(Wade, 1926)
<i>Megalops nolfi</i>	
<i>Albulidae</i> indeterminate	
<i>Osmeroides mississippiensis</i>	
<i>Osmeroides</i> sp.	
<i>Pterothrissus</i> sp.	
<i>Anguilla?</i> <i>chickasawae</i>	
<i>Muraenanguilla unionensis</i>	
<i>Osteoglossum?</i> <i>tavernei</i>	
<i>Kokenichthys navis</i>	
<i>Kokenichthys ripleysensis</i>	
<i>Apateodus crenellatus</i>	
<i>Thrax acutus</i>	
<i>Paraulopus pseudoperca</i>	
<i>Choctawichthys cepoloides</i>	
<i>Cowetaichthys alabamae</i>	
<i>Cowetaichthys carnevalei</i>	
<i>Tippaha cavata</i>	
<i>Tippaha mythica</i>	
<i>Hoplopteryx langfordi</i>	
<i>Hoplopteryx oscitans</i>	
<i>Eutawichthys choctawae</i>	
<i>Eutawichthys maastrichtiensis</i>	
<i>Eutawichthys zideki</i>	
<i>Argyroberyx?</i> <i>Dockeryi</i>	
<i>Ossulcus labiatus</i>	
<i>Indeterminate huddlestoni</i>	
<i>Indeterminate severnensis</i>	
<i>Otolithopsis cumatilis</i>	

<i>Arius subtilis</i>	
<i>Vorhisia vulpes</i>	
Chondrichthyes:	(Case and Schwimmer, 1988) (Kirkland et al., 2013)
<i>Lonchidion</i> sp.	
<i>Cretolamna</i> sp.	
Unidentified shark tooth 1	
Unidentified shark tooth 2	
Unidentified shark tooth 3	
Unidentified shark tooth 4	
Unidentified shark vertebra 1	
Unidentified shark vertebra 2	
Reptilia:	(Wade, 1926)
Mosasauridae	
<i>Mosasaurus</i> sp.	
Ichnofossils:	(Bishop, 2016)
<i>Thalassinoides</i>	

REFERENCES

- Adl, S.M., Simpson, A.G.B., Farmer, M.A., Andersen, R.A., Anderson, O.R., Barta, J.R., Bowser, S.S., Brugerolle, G., Fensome, R.A., Frederico, S., James, T.Y., Karpov, S., Kugrens, P., Krug, J., Lane, C.E., Lewis, L.A., Lodge, J., Lynn, D.H., Mann, D.G., McCourt, R.M., and Mendoza, L., 2005. The new higher level classification of eukaryotes with emphasis on the taxonomy of protists. *Journal of Eukaryotic Microbiology* 52(5): 399-451.
- Alexander, C.I., 1929. The Ostracoda of the Cretaceous of north Texas. *University of Texas Bulletin* 2907: p. 52, pl. 2, fig. 3.
- Alexander, C.I., 1933. Shell structure of the ostracode genus *Cytheropteron* and fossil species from the Cretaceous of Texas. *Journal of Paleontology* 7: 181-214.
- Bandel, K. and Dockery III, D.T., 2016. Mollusca of the Coon Creek Formation in Tennessee and Mississippi with a systematic discussion of the Gastropoda. *Bull. Alabama Mus. Nat. Hist.* 33: 34-96.
- Berg, L.S., 1958. System der rezenten und fossilen Fischartigen und Fische. Berlin, VEB Deutscher Verlag der Wissenschaften. pp. 311.
- Berry, E.W., 1925. Upper Cretaceous Ostracoda from Maryland. *American Journal of Science, Series 5.* 9: 481-487.
- Berry, W. and Kelley, L., 1929. The Foraminifera of the Ripley formation on Coon Creek, Tennessee. *Proceedings of the United States National Museum* 76(2816): 1-20.
- Bishop, G.A., 1983. Fossil decapod crustacea from the Late Cretaceous Coon Creek Formation, Union County, Mississippi. *Journal of Crustacean Biology*, 3(3): 417-430.
- Bishop, G.A., 2016. The Coon Creek decapod assemblages; Cretaceous marine paleocommunities of northern Mississippi and Tennessee. *Bull. Alabama Mus. Nat. Hist.* 33(2): 7-20.
- Brasier, M.D., 1980. Figure 13.10, p. 101 in: *Microfossils*. George Allen and Unwin, London, 193 p.
- Bronn, H.G., 1862. Die Klassen und Ordnungen der Weichthiere (Malacozoa). *Kopfflose Weichthiere (Malacozoa Acephala) Weichthiere*. Leipzig pp. 1306 + 118 pl.
- Calkins, G.N., 1933. The biology of the Protozoa, second edition. Philadelphia, Lea and Febiger. pp. 623.

- Carsey, D.O., 1926. Foraminifera of the Cretaceous of central Texas. University of Texas bulletin 2612.
- Case, G.R. and Schwimmer, D.R., 1988. Late Cretaceous fish from the Blufftown Formation (Campanian) in western Georgia. *Journal of Paleontology* 62(2): 290-301.
- Conrad, T.A., 1860. Descriptions of new species of Cretaceous and Eocene fossils of Mississippi and Alabama: Philadelphia Academy of Natural Sciences, Journal, 2nd series, v. 4, p. 275-298, 2 pl.
- Cope, E.D., 1871. Contribution to the Ichthyology of the Lesser Antilles. *Transactions of the American Philosophical Society, New Series* 14(3): 445-483.
- Coryell, H.N., Sample, C.H., Jennings, P.H., 1935. *Bairdoppilata*, a new genus of Ostracoda, with two new species. *American Museum Novitates* 777: 1-5.
- Cox, L.R., 1960. Thoughts on the classification of the Gastropoda: *Proceedings of the Malacological Society of London*, v. 33, p. 239-261.
- Crane, M.J., 1965. Upper Cretaceous Ostracodes of the Gulf Coast Area. *Micropaleontology* 11(2): 191-254.
- Cushman, J.A., 1931. A preliminary report on the Foraminifera of Tennessee. Tennessee. Division of Geology. Bulletin 41: 1-113.
- Cushman, J.A., 1936. Notes on some American Cretaceous *Fronicularias*. Contributions from the Cushman laboratory for foraminiferal research. 12(1): 11-22.
- Cushman, J.A., 1938. Additional new species of American Cretaceous Foraminifera. Contributions from the Cushman laboratory for foraminiferal research. 14(2): 31-50.
- Cushman, J.A., 1939. New American Cretaceous Foraminifera. Contributions from the Cushman laboratory for foraminiferal research. 15(4): 89-93.
- Cushman, J.A., 1940. Cushman Lab. Foram. Research Contr., vol. 16, p. 38, pl. 7, figs. 3-5.
- Cushman, J.A., 1946. Upper Cretaceous foraminifera of the Gulf Coastal Region of the United States and adjacent areas. U.S. Geological Survey Professional Paper 206.
- Cushman, J.A. and Ozawa, Y., 1928. An outline of a revision of the Polymorphinidae. Contributions from the Cushman laboratory for foraminiferal research 4(1): 13-

- Cushman, J.A. and Deaderick, W.H., 1944. Cretaceous Foraminifera from the Marlbrook Marl of Arkansas. *Jour. Paleontology*, vol. 18, p. 335, pl. 52, fig. 10.
- Cuvier, G., 1795. Second Mémoire sur l'organisation et les rapports des animaux à sang blanc, dans lequel on traite de la structure des Mollusques et de leur division en ordre, lu à la société d'Histoire Naturelle de Paris, le 11 prairial an troisième [30 May 1795]. *Magazin Encyclopédique, ou Journal des Sciences, des Lettres et des Arts*, 1795 [1. année] 2: 433-449.
- Delage, Y. and Hérourard, E., 1896. *Traité de zoologie concrete: La cellule et les Protozoaires*. Paris, Schleicher frères. v. 1, pp. 527.
- Dockery III, D.T., 1992. A Guide to The Frankstown Vertebrate Fossil Locality (Upper Cretaceous), Prentiss County, Mississippi. Mississippi Department of Environmental Quality Office of Geology. p. 1-43.
- Dockery III, D.T., 1993. The Streptoneuran Gastropods, Exclusive of the *Stenoglossa*, of The Coffee Sand (Campanian) of Northeastern Mississippi. *Bulletin 129*, Mississippi Department of Environmental Quality Office of Geology. p. 1-191.
- Dockery III, D.T., 2020. Cretaceous (Campanian) Bivalves of the Coffee Sand in Mississippi Illustrated. Mississippi Department of Environmental Quality Office of Geology. p. 1-100.
- Estes, R., 1964. Fossil vertebrates from the Late Cretaceous Lance Formation, eastern Wyoming. *University of California Publications in Geological Sciences* 49.
- Follo, J. and Fautin, D., 2001. "Echinoidea" (On-line), Animal Diversity Web. Accessed June 25, 2022 at <https://animaldiversity.org/accounts/Echinoidea/>.
- Gabb, W.M., 1859. Catalogue of the invertebrate fossils of the Cretaceous formation of the United States, p. 1.
- Gabb, W.M., 1877, Notes on American Cretaceous fossils with descriptions of some new species: Philadelphia Academy of Natural Sciences, *Proceedings* 1876, v. 28, p. 276-324.
- Gervais, P., 1852. *Zoologie et Paléontologie Françaises (Animaux Vertébrés) ou Nouvelles Recherches sur les Animaux Vivants et Fossiles de la France* [French Zoology and Paleontology (Vertebrate Animals) or New Research on the Living and Fossil Animals of France] 1–3: 1-274.

- Glikman, L.S., 1958. Rates of evolution in Lamnoid sharks. *Doklady Akademii Nauk SSSR*, 123(3): 568–571.
- Gluckman, L.S., 1964. Sharks of the Paleogene and their stratigraphic significance. Moscow, Nauka Press, 266 p.
- Grube, A.E., 1850. Die Familien der Anneliden. *Archiv für Naturgeschichte*, Berlin. 16(1): 249-364.
- Haeckel, E., 1874. Die Gastraea-Theorie, die phylogenetische Classification des Thierreichs und die Homologie der Keimblätter. *Jenaische Zischr Naturw* 8: 1-55.
- Herman, J., 1977. Les sélaciens des terrains néocrétacés & paléocènes de Belgique & des contrées limitrophes. *Eléments d'une biostratigraphie intercontinentale. Mémoires pour servir à l'explication de Cartes Géologiques et Minières de la Belgique* 15.
- Huxley, T.H., 1880. On the application of the laws of evolution to the arrangement of the Vertebrata, and more particularly of the Mammalia. *Proceedings of the Zoological Society of London* 43, 649-662.
- Israelsky, M.C., 1929. Upper Cretaceous Ostracoda of Arkansas. *Arkansas, Geol. Survey, Bull.*, no. 2.
- Jennings, P.H., 1936. A microfauna from the Monmouth and Basal Rancocas Groups of New Jersey. *Bulletin of American Paleontology* 23(78): 159-234.
- Jones, T.R., 1849. A monograph of the Entomostraca of the Cretaceous Formation of England. *Monograph of the Palaeontographical Society London* 3: 1-40.
- Kirkland, J.I., Eaton, J.G., and Brinkman, D.B., 2013. Elasmobranchs from Upper Cretaceous freshwater facies in southern Utah, in: *At the top of the grand staircase*. Editors Titus, A.L. and Loewen, M.A. Indiana University Press, Bloomington. P. 153-194.
- Klein, T., 1754. *Ordre naturel des oursins de mer et fossiles, avec des observations sur les piquants des oursins de mer et quelques remarques sur les bélemnites*. C.J.B. Bauche, Paris 1-235.
- Kornecki, K.M., Feldmann, R.M., and Schweitzer C.E., 2017. Decapoda (Crustacea) of the Coon Creek Formation (Maastrichtian) of Mississippi and Tennessee. *Bulletin of the Florida Museum of Natural History* 53(6): 269-334.
- Lamarck, J.B.M., 1799. *Prodrome d'une nouvelle classification des coquilles, comprenant une rédaction appropriée des caractères génériques, et l'établissement d'un grand nombre de genres nouveaux*. *Mémoires de la Société d'Histoire Naturelle de Paris*

1: 63-91.

Lamarck, J.-B. de., 1802 (privately published, reprinted 1906). Discours d'Ouverture, Prononcé le 27 floréal An 10, au Muséum d'Histoire naturelle. Recherches sur l'organisation des corps vivans. Bulletin Scientifique de la France et de la Belgique. (5th series) 40: 483-517 [Les Annelides p. 494].

Lamarck, J. B. P. A. de M. de., 1816. Tableau encyclopédique et méthodique des trois règnes de la nature, Mollusques et polypes divers. Part 23 [Livraison 84, 14 December 1816], Tome 3, pp. 1-16, pls. 391-431, 431 bis, 431 bis*, 432-488, Paris: Vve Agasse.

Latreille, P.A., 1802. Histoire naturelle, générale et particulière des Crustacés et des Insectes. Histoires des Cypris et des Cytherées 8 (4): 232-254.

Laurenti, J.N., 1768. Specimen medicum, exhibens synopsin reptilium emendatam cum experimentis circa venena et antidota reptilium austriacorum [Medical ideas, showing an emended synopsis of the reptiles together with experiences in poisoning by and antidotes of Austrian reptiles]. Published and printed by Johann Thomas von Trattner, Vienna.

Levinson, G.M.R., 1883. Systematisk-geografisk Oversigt over de nordiske Annulata, Gephyrea, Chaetognathi og Balanoglossi. Videnskabelige Meddelelser fra Dansk naturhistorisk Forening i København, 1882. 160-251.

Leske, N.G., 1778. Jacobi Theodori Klein naturalis dispositio echinodermatum, edita et descriptionibus novisque inventis et synonymis auctorem aucta. Addimenta ad I. T. Klein naturalem dispositionem Echinodermatum, G. E. Beer, Leipzig 1-278.

Linnaeus, C., 1758. Systema Naturae per Regna Tria Naturae, Secundum Classes, Ordines, Genera, Species, cum Characteribus, Differentiis, Synonymis, Locis. Editio Decima 1: 1-824.

Lovén, S., 1847. Malacozoologi. Öfversigt af Kongliga Vetenskaps Akademiens Förhandlingar. Volume 4, pp.175-199, pis. 2-6.

Mikhalevich, V.I., 1980. Sistematika i evolyutsiya foraminifera v svete novykh dannykh po ikh tsitologii i ul'trastrukture [Systematics and evolution of foraminifera in the light of new data on their cytology and ultrastructure]. Trudy Zoologicheskogo Instituta 94: 42-61.

Mikhalevich, V.I., 1993. New higher taxa of the subclass Nodosariata (Foraminifera). Zoosystematica Rossica 2: 5-8.

- Montfort, P. [Denys de], 1808-1810. Conchyliologie systématique et classification méthodique des coquilles. Paris: Schoell. Vol. 1: pp. lxxxvii + 409 [1808]. Vol. 2: pp. 676 + 16 [1810 (before 28 May)].
- Morton, S.G., 1834. Synopsis of the organic remains of the Cretaceous Group of the United States. Philadelphia: Key & Biddle. 88 pp., 19 pls., + Appendix, 8 pp.
- Ogg J., Ogg G., and Gradstein F., 2016. A concise geologic time scale. Elsevier, Amsterdam, p 240.
- Oppel, M., 1811. Die Ordnungen, Familien und Gattungen der Reptilien als Prodom einer Naturgeschichte Derselben. Joseph Lindauer, München xii-86.
- Orbigny, A. D. d', 1826. Tableau méthodique de la classe des Céphalopodes. Annales des Sciences Naturelles 7: 96-169, 245-314.
- Orbigny, A. D. d', 1839. Foraminifères, in de la Sagra R., Histoire physique, politique et naturelle de l'île de Cuba. A. Bertrand. 1-224, p. XXXIX, 131.
- Patterson, C., 1966. British Wealden sharks. Bull Brit Mus (Nat Hist) Geol 11: 283-349.
- Philippi, R.A., 1844. Enumeratio molluscorum Siciliae cum viventium tum in tellure tertiaria fossilium, quae in itinere suo observavit. Vol. 2.. Halle [Halis Saxorum]: Eduard Anton. iv + 303 pp., pls 13-28.
- Plummer, H.J., 1931. Some Cretaceous foraminifera in Texas. University of Texas bulletin 3101: 109-203.
- Puckett, T.M., 1992. Distribution of Ostracodes in the Upper Cretaceous (Late Santonian through Middle Maastrichtian) of Alabama and Mississippi. Gulf Coast Association of Geological Societies 42: 613-631.
- Puckett, T.M., 1994. New Ostracoda species from an Upper Cretaceous oyster reef, northern Gulf Coastal Plain, U.S.A. Journal of Paleontology 68(6): 1321-1335.
- Puckett, T.M., 2009. On the global distribution of Late Cretaceous ostracodes: the genus *Bicornicythereis* (n. gen.), with notes on *Curfsina*. Micropaleontology 55(4): 345-364.
- Quenstedt, E.A., 1856. Der Jura, Lfrg. 2: 209-368, p. 292.
- Rafinesque, C.S., 1815. Analyse de la nature ou Tableau de l'univers et des corps organisés. [Book]. 1-224, (self-published) Palermo.

- Rathbun, M.J., 1917. New Species of South Dakota Cretaceous Crabs. *Proceedings of the United States National Museum* 52(2182): 385-391.
- Rathbun, M.J., 1923. Decapod Crustaceans from the Upper Cretaceous of North Carolina. *North Carolina Geological and Economic Survey* 5: 403-408.
- Rathbun, M.J., 1935. Fossil Crustacea of the Atlantic and Gulf Coastal Plain. *Geological Society of America Special Paper* (2): 1-160.
- Regan, C.T., 1909. Descriptions of new marine fishes from Australia and the Pacific. *Annals and Magazine of Natural History*, ser. 8, 4(23): 438-440.
- Reuss, A.E., 1845. Die Versteinerungen der böhmischen Kreideformation. E. Schweizerbart'sche Verlagsbuchhandlung und Druckerei, Stuttgart. 1: 1-58.
- Reuss, A.E., 1860. Die Foraminiferen der westphälischen Kreideformation. *Sitzungsberichte der mathematisch-naturwissenschaftlichen Classe der kaiserlichen Akademie der Wissenschaften* 40 (8): 147-238.
- Roberts, L.N.R., and Kirschbaum, M.A., 1995. Paleogeography of the Late Cretaceous of the Western Interior of middle North America – coal distribution and sediment accumulation. *U.S. Geological Survey Professional Paper* 1561.
- Roemer, F., 1839. Verstein. norddeutschen Oolithengebirges, Nachtrag., p. 48, pl. 22, fig. 29.
- Rosen, D.E., 1973. Interrelationships of higher euteleostean fishes. In: Greenwood P.H., Miles R.S. & Patterson C. (Eds): *Interrelationships of fishes*: 397-513. Academic Press, London, 536 pp.
- Sadler, P.M., 2010. Constrained optimization approaches to the paleobiologic correlation and seriation problems: a users' guide and reference manual to the CONOP family of programs, version 7.61, copyright 1998-2010, P. M. Sadler.
- Sakashita, M., Sato, M., and Kondo, S., 2019. Comparative morphological examination of vertebral bodies of teleost fish using high-resolution micro-CT scans. *Journal of Morphology* 280: 778-795.
- Sandidge, J.R., 1932. Fossil Foraminifera from the Cretaceous, Ripley Formation, of Alabama. *American Midland Naturalist* 13(5): 312-318.
- Sars, G.O., 1866. Oversigt af Norges marine Ostracoder. *Forhandlinger i Videnskabs-Selskabets*, p. 1-13.

- Schwarzahns, W., 2019. Reconstruction of the fossil marine bony fish fauna (Teleostei) from the Eocene to Pleistocene of New Zealand by means of otoliths. *Memorie della Società Italiana di Scienze Naturali e del Museo Civico di Storia Naturale di Milano*, 46: 3-326.
- Sollas, W.J., 1877. On the Perforate Character of the Genus *Webbina*, with a Notice of Two New Species, *W. Lævis* and *W. Tuberculata*, from the Cambridge Greensand. *Geological Magazine*. 4(3): 102-105.
- Stephenson, M.B., 1936. Shell structure of the ostracode genus *Cytheridea*. *Journal of Paleontology* 10: 695–703.
- Stoliczka, F., 1868. Cretaceous fauna of southern India vol. II: Gastropoda of the southern rocks of India. *Memoirs of the Geological Survey of India*, 497 pp.
- Stringer, G.L., Schwarzahns, W., Phillips, G., and Lambert, R., 2020. Highly diversified Late Cretaceous fish assemblage revealed by otoliths (Ripley Formation and Owl Creek Formation, Northeast Mississippi, USA). *Riv. It. Paleontol. Strat.*, 126(1): 111-155.
- Swain, F.M., 1952. Ostracoda From Wells in North Carolina: Part 2. Mesozoic Ostracoda. U.S. Geological Survey Professional Paper 234-B.
- Thompson, D.E. and Dockery III, D.T., 2016. *The Geology of Mississippi*. University Press of Mississippi, 751 p.
- Wade, B., 1921. The fossil annelid genus *Hamulus* Morton, an operculate serpula. *Proceedings of the United States National Museum* 59: 41-46.
- Wade, B., 1926. The fauna of the Ripley Formation on Coon Creek, Tennessee. U.S. Geological Survey Professional Paper 137.
- Woodward, A.S., 1901. Catalogue of fossil fishes in the British Museum (Natural History), Part IV. Trustees of the British Museum (Natural History), London, 636 pp.