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Stratigraphic Interpretations of Eocene Winona and Tallahatta Formations in the Duffee Quadrangle, MS

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by

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Abstract

Outcrops and exposures of the Winona and Tallahatta formations in the Duffee Quadrangle in Newton and Lauderdale counties were mapped and analyzed. The rock type, composition, structures, and fossils were identified at each site; unit thicknesses were measured, and stratigraphic relationships were analyzed for available exposures. Using GPS coordinates, each site was mapped on Google Earth Pro. The data collected at each site, aerial photographs, and topographic maps were used to identify each formation. The variability between previous works and this study was analyzed. The primary rock type found in the Tallahatta Formation is siliciclastic silty claystone and sandstone; some units were glauconitic, and the color ranges from tan to olive green. The Winona Formation is glauconitic iron-rich red sandstone. Storm deposits were identified in the Winona Formation and in the Tallahatta Formation; there were fining-upward sequences in these deposits in the sandstone units. Some layers of sandstone in both formations contained bivalve and gastropod molds.

Keywords: Tallahatta, Winona, fossils, glauconite, sandstone, storm deposits

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I thank my family for putting up with me bringing endless rock samples into the house and tearing up the pasture looking for more. Finally, I thank my grandfather for inspiring me to become a geologist. Without his guidance when I was younger, I would have probably never pursued this career. He passed away during my last semester at USM, but his passion for geology will live on through me.

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Chapter 1: Introduction

Stratigraphic and lithologic surveys provide a multitude of information for geological interpretations. The units in this research project were analyzed to get local lithologic descriptions of exposed formations. The rock type, sediment texture, grain size, composition, and geologic structures of each unit were described. These findings, along with GPS coordinates on Google Earth, allow interpretations to be made on a local level.

Despite the number of studies conducted on the Tallahatta and Winona formations in Alabama and Georgia (Mancini and Tew, 1988 and 1993), geologic mapping and research need to be performed on a local scale throughout the South. Many formations are compositionally variable across different states and are separated into members based on these differences. In Mississippi, many formations are studied for their economic use as mineral resources and aquifer sources; however, geologic studies for the purpose of analyzing depositional environments in geologic history are also important to understand and compare to current processes. The purpose of this study is to expand the information known about these formations at a smaller scale in the Duffee Quadrangle in Newton and Lauderdale counties. One hypothesis is that the Winona Formation formed, in part, as storm deposits. Other unknowns about these units include their biostratigraphic characteristics.

The goals of this study are:

- To analyze sedimentological characteristics of the observed units.
- To construct a stratigraphic column and maps to compare to previous maps.
- To determine depositional environment and characteristics.
- To observe fossil content within the study area.

1.1 Location

All the areas in this study are located within the Duffee 7.5-minute topographic Quadrangle in Newton and Lauderdale counties in Mississippi. Sites 1-3 are located along McNeil Road (labeled as Hickory Little Rock Road in Figure 1). Sites 1, 2, and 2.5 are on private property belonging to the Johnson family south of McNeil Road. Site 3 is privately owned as well, but it is leased yearly for hunting; access to the property was granted after hunting season had ended to avoid possible injury. Site 4 is on Bogue Statineau Road surrounded by private property (Figure 2). Sites 1-3 are in the NW corner of section 29 in T7N R13E (Figure 3). Site 4 is east of the Newton/Lauderdale county border at section 31 in T7N R14E and section 6 in T6N R14E (Figure 4). These locations were observed in the Fall of 2018 and the Winter of 2019; however, some samples had already been collected on the properties due to this being owned by my family.

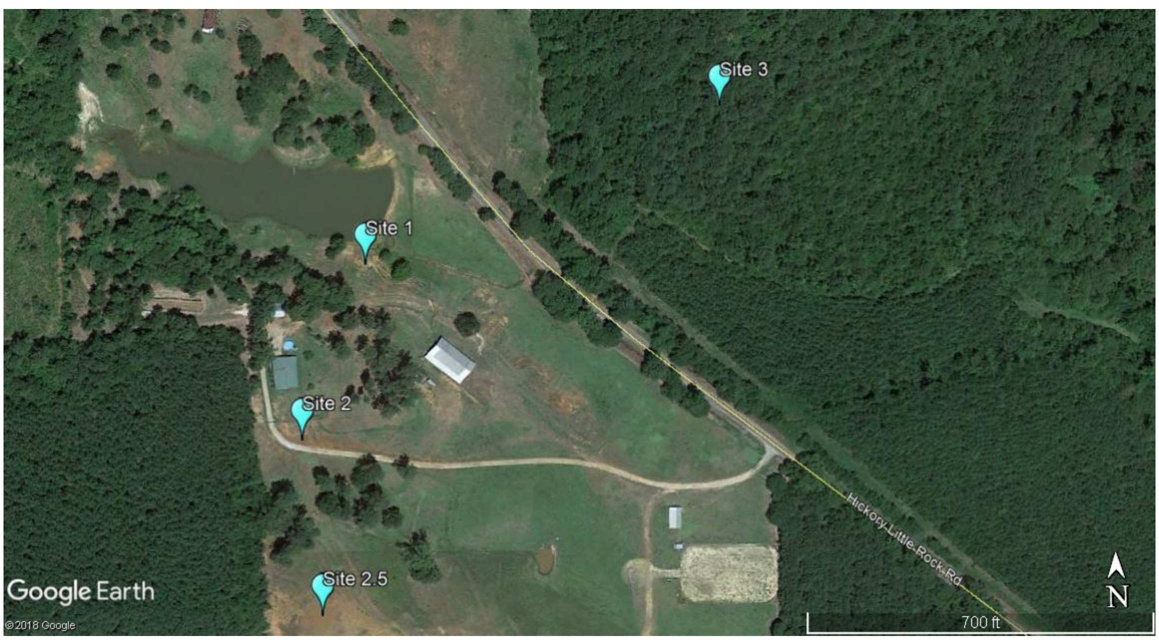


Figure 1. Google Earth image of the study area (Sites 1-3). Sites 1, 2, and 2.5 were observed on 625 McNeil Rd in Decatur, MS. Site 3 was observed north of these sites on private property; this area has been cleared of all trees since this photograph was taken (Google Earth Pro, 2015). Sites 1-2.5 were observed in the summer and fall of 2018, and Site 3 was observed December 2018- January 2019.

Figure 2. Google Earth image of the study area (Site 4). This area observed east of the Newton County and Lauderdale County border was mapped on November 10, 2018 and February 1, 2019 on Dean Road and Bogue Statineau Road. Image from Google Earth Pro dated in 2015. The border between counties is the light blue line on the west side of the image (oriented due north).

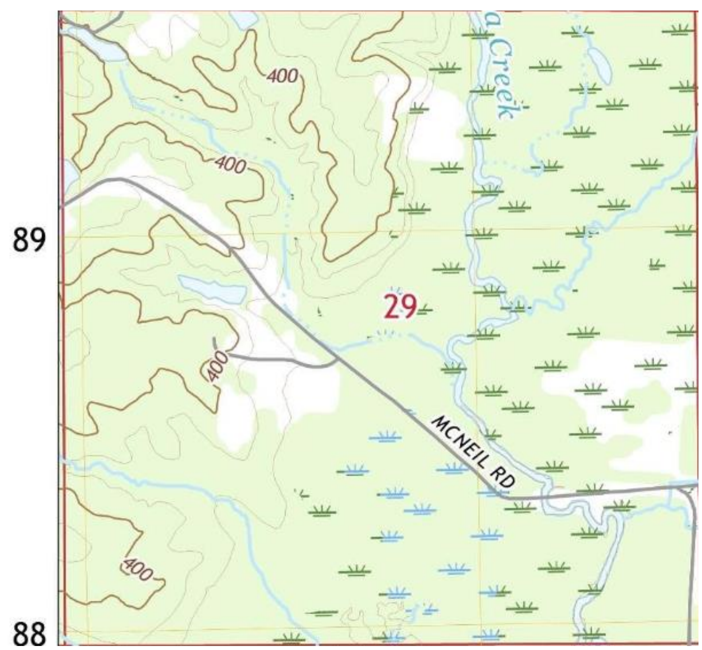


Figure 3. Topographic map of McNeil Road, Decatur, MS (Sites 1-3). This area is in Township 07 N, Range: 13 E, Section 29. Cut from the 2018 Duffee quadrangle topographic map with a scale of 1:24,000 (datum: NAD83) The focus was on the west side of the section (Thompson, 2018).

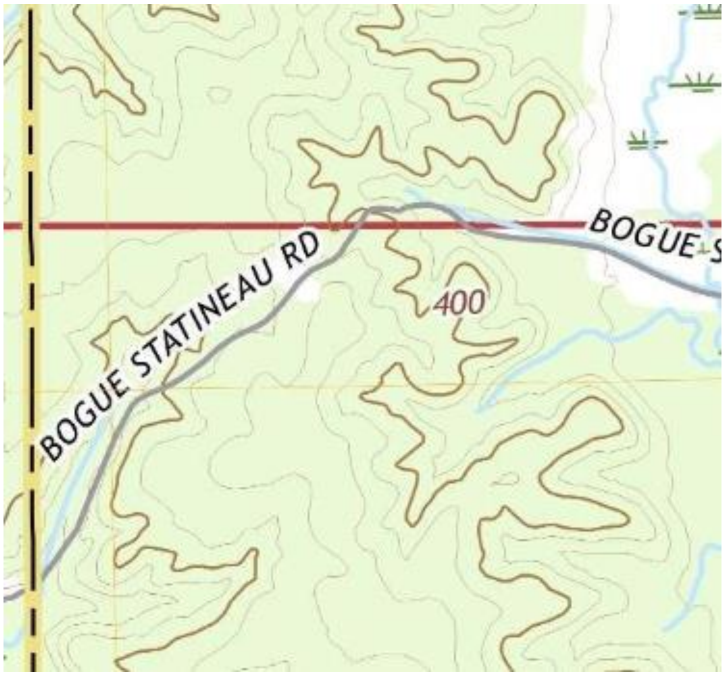


Figure 4. Topographic map of Bogue Statineau Road (Site 4). The study area is along Bogue Statineau Road in Lauderdale County. The region is in T7N, R14E, section 31 and T6N, R14E, section 6 (Thompson, 2018).

Site 1 (Figure 1): 32° 25’14.18” N 88°59’42.50” W. The elevation is at approximately 365-380 feet, and the area consists of mostly loose boulders and some in-place ledges. The area did not have enough section in place to make a stratigraphic column; the area was mostly exposed because of erosion and a horse made trail going around the SE side of the pond. After the area was studied, red mud washed down the hill and covered part of the rocks; hay was placed around the washout to help with erosion.

Site 2 (Figure 1): 32°25’10.74” N 88°59’44.00” W. The elevation is at approximately 395-405 feet, and the outcrop is mostly composed of massive beds exposed within a drainage ditch along a gravel driveway running east downslope. Site 2.5 is south of Site 2 and mostly consists of eroded rocks exposed from erosion.

Site 3 (Figure 1): 32°25’17.11” N 88°59’ 34.08” W. The elevation is at approximately 355 to 415 feet from the base of the road to the top of the hill. The layers are exposed on the road due to high relief and traffic from vehicles. A ditch about 1 to 2 feet deep within the road exposes units as well (Figure 5).

Figure 5. Picture of Site 3 outcrop. This site is north of McNeil Road on private property and has been exposed due to logging and hunting traffic. Picture dated 02/03/2019.

Site 4: 32°23’53.01” N 88°54’38.61” W on the border of section 31 T7N R14E and section 6 T6N R14E to the east of the Newton County/Lauderdale County border. The study area is on Bogue Statineau Road. The measured outcrop is south of the road (Figure 2).

Chapter 2: Literature Review and Background

2.1 Lithology

This research project focuses on the Winona and Tallahatta formations in the Claiborne Group. These formations were deposited in the Eocene Epoch, which occurred 56 to 34 million years ago in the Paleogene Period (Merrill et al., 1985). The Winona Formation is an olive-green glauconitic sandstone that is iron-rich, fossiliferous, and contains the mineral limonite; on exposed weathered surfaces, the formation is dark red to orange from iron staining. The sandstone is generally fine to medium grained and poorly sorted; the main fossils identified are mollusks (i.e., seashells). Underneath the Winona Formation, the Tallahatta Formation contains the Neshoba Sand Member and the Basic City Shale Member. The Neshoba Sand is red, glauconitic sandstone that is micaceous and nonfossiliferous. The Basic City Shale is light to dark gray and varies from siltstone and sandstone to shale; the shale is interbedded within the units of sandstone and siltstone (Merrill et al., 1985). In the upper units of the Basic City Shale, burrowing is common, and fossils are found in small quantities. The Tallahatta Formation is also known for its compact claystone called buhrstone.

The Claiborne Group consists of the Tallahatta Formation, Winona Formation, and Zilpha Clay in Mississippi. The Meridian Sand Member, Basic City Shale, and Neshoba Sand Member make up the Tallahatta Formation in central Mississippi; however, northern Mississippi includes the Holly Springs Sand Member. The Tallahatta Formation averages approximately 90 feet in thickness in eastern Mississippi, but it is about 200 feet thick in north-central Mississippi (Cushing, Boswell, and Hosman, 1964). Light shale, claystone, and siltstone that is fossiliferous and is found in the Basic City

Shale Member; orthoquartzite, or buhrstone, is also common. The Basic City Shale contains transgressive and highstand shelf deposits (Savrda et al., 2010). The Neshoba Sand Member is clayey and micaceous sandstone, but it does not contain fossils. The Winona Sandstone mapped in Mississippi is glauconitic, fossiliferous sandstone and claystone that is approximately 50 feet thick. The Zilpha Clay is carbonaceous, glauconitic, fossiliferous dark-gray claystone; the formation is up to 75 feet thick to only a few feet thick (Cushing, Boswell, and Hosman, 1964). Some of these members pitch out in different regions of Mississippi, Alabama, and Georgia.

The Tallahatta Formation and Winona Formation have been identified in Newton and Lauderdale counties. In the Tallahatta Formation, the Basic City Shale Member contains siltstone, claystone, and sandstone and is bioturbated; the color is generally greenish-gray, and the top layer is fossiliferous. The Neshoba Sand Member contains moderate reddish-brown sandstone that is micaceous, coarse to fine grained, and poorly sorted. The Winona Formation is iron-rich, dark reddish-brown, glauconitic, fossiliferous, and poorly sorted sandstone (Dockery and Thompson, 2016).

2.2 Structures and Fossils

Certain structures and fossils are unique to the Tallahatta Formation and the Winona Formation. Liesegang banding, crossbedding, and bioturbation have been identified in the Tallahatta Formation, and multiple fossils and glauconite have been found in the Winona Formation. In previous research, *Skolithos* ichnofacies have been identified in the Tallahatta Formation. Some of the beds deposited in a shallow marine environment and contain storm deposits. Organisms that survived transportation by the storms can change the ichnofacies that are formed; some storm beds within the Tallahatta

Formation contain *Skolithos* and *Cruziana* ichnofacies. Ichnofacies have also been altered by certain organisms moving to avoid the effects of the storms (Savrda et al., 2010).

The Tallahatta Formation has been studied in Alabama (Copeland et al., 1989) and Georgia, as well as Mississippi. Few calcareous fossils have been found, so it has been difficult to determine a more precise age using biostratigraphy (Bybell and Gibson, 1985). Limited sampling and sparseness of foraminifera and other microfossils within the Tallahatta Formation have also presented a problem. The lack of microfossils is explained by the organisms' inability to survive in the depositional environment and/or their ability to be preserved within the rock units. Bybell and Gibson (1985) decided that the best way to locate calcareous nannofossils is within fresh, calcareous outcrops and cores. These researchers determined an approximate age for the base of the Tallahatta Formation in Alabama between zones NP12 and NP14 in the lower Eocene using calcareous nannofossils; they also identified a global temperature peak based on the nannofossil diversity. Fossils are important in guiding geologic studies.

Bromley's book (1990) was used to gain insight on various trace fossils. Other books were used for identifying trace fossils and determining the fossils' significance within the rock unit (Ekdale, Bromley, and Pemberton, 1984). Trace fossils like burrows can hold important information regarding depositional environment as well as what life can survive (Frey, 1975). The preservation of burrows in a unit where organisms are not present can indicate an approximate size of the organism as well as depth of the water. Trace fossils found in exposed units and boreholes can also provide insight on what paleoenvironments were present (Ekdale, Bromley, and Pemberton, 1984).

Copeland et al. (1989) authored a guidebook for Tertiary bio- and lithostratigraphy in central Alabama. The Tallahatta Formation, Lisbon Formation (Winona Sand) and Gosport Sand are identified in the Gulf Coastal Plains. Based on planktonic foraminifera identified, the Tallahatta Formation is in the Ypresian NP12 Zone to the Lutetian NP15 Zone, and the Lisbon Formation is assigned to the NP15 zone to the NP17 Zone (Copeland et al., 1989). Mancini and Tew (1988) also presented data for the background of the geology in Alabama; this gave insight into what could be found in Mississippi as well as how to approach geologic field work. The Geology of Mississippi (Dockery and Thompson, 2016) was used to survey previously studied areas within Mississippi including Lauderdale and Newton counties. The type localities for the formations include the Winona Formation in Winona, Montgomery County, Mississippi; Tallahatta Formation in Tallahatta Hills, Choctaw County, Alabama; and the Basic City Shale Member in Basic City, Clarke County, Mississippi (Mancini and Tew, 1993).

Mancini and Tew's (1993) study on sequence stratigraphy in the Mississippi Embayment and the book on planktonic foraminifera by Pearson et al. (2006) were studied before data were collected to gain insight on data that could be collected. The Winona Formation was deposited as a transgressive systems tract, and the Tallahatta Formation was deposited as highstand, transgressive, and lowstand systems tracts (Mancini and Tew, 1993). However, sequences were not identified in any of the studied units, and foraminifera were not found in the samples collected. These sources were still needed to interpret sequences and forams. These resources could be useful for future projects were certain features and fossils are identified.

Chapter 3: Materials and Methodology

3.1 Sample Collection and Field Work

Two main areas were observed in this study within the Duffee Quadrangle; there are three sites indicated in Figure 1 and one site in Figure 2. Locations were mapped using the Duffee quadrangle topographic map (Thompson, 2018) for each location. GPS coordinates were recorded using Google Earth on a cell phone and mapped on Google Earth Pro. The areas were first surveyed for fresh, well-preserved exposures. Various materials were required to conduct research for this project. In areas with exposed units, thicknesses were measured using a measuring stick marked with feet and inches. Where units were covered, a Johnson hand-held sight level was used to ensure lateral continuity at a distance; it was used to maintain contacts from one spot to another. The level was also useful in obtaining unit thicknesses measured in 5-foot intervals. A rock hammer was used for exposing fresh surfaces.

Rocks were analyzed and described based on grain texture, composition, and fossil content. A 10x magnification hand lens was used to examine grain size and texture, and a grain size card was used to measure grain size and roundness. Dilute hydrochloric acid (10%) was used for testing for calcium carbonate (calcite) in the rocks. Samples were collected in 7x11” canvas bags as well as plastic sandwich bags from fresh surfaces. Eighteen samples were taken at Site 4 (Figure 2) to search for microfossils, and various rock samples were taken from the other sites to analyze sediment characteristics and fossils.

3.2 Laboratory Work

The first step in this experiment was deciding which samples could be sieved for analysis. A mallet was used to break down the samples that were compact. Samples collected from Site 4 were sifted through a 180 µm sieve to separate silts and clays from sand-sized grains; then, they were dried overnight at 75 °C in a Stabil-Therm Gravity Oven on medium to low power. The samples were placed in a tin pie pan; the sediment was spread across the bottom of the pan for even distribution for quicker drying. Some samples were left in the oven for a period of 6 hours at 75 °C to 100 °C on medium heat or on low heat overnight at 75 °C. Many samples were dried around scheduled classes and building hours, and times and heat were adjusted accordingly. The samples were then placed in labeled paper envelopes.

A microscope and a paint brush (size 000) were used to sift through and analyze the samples place on a copper grid tray; samples were picked through to search for fossils like gastropods, bivalves, and microfossils. Only samples that could be broken down and sifted were processed in the sieve; the characteristic buhrstone of the Tallahatta Formation was too compact to properly sift. Samples from sites 1-3 were not sieved because environmental conditions were not stable for the preservation of fossils.

Certain programs and websites were also used to aid in the research. The United States Topography Survey was used to obtain topographic maps of the area like the Duffee quadrangle map (Thompson, 2018). Gimp 2.10.6 was used for photo editing and manipulation; this program was free compared to the preferred program Illustrator. Sed Log 3.1 was used to create a stratigraphic column for the measured sections; it illustrates the identified units as well as their age, thicknesses, lithology, fossils, structures, and descriptions. The units are represented in meters and feet on the stratigraphic column; this program uses metric units, but the English scale was added afterwards using Gimp's layering feature.

Chapter 4: Results

4.1 Unit Lithology

Site 1: Tallahatta Formation

Site 1 (Figure 1) is located at an exposure near a pond (Figure 6). The area consists of large boulders of medium to coarse-grained, tan sandstone and mudstone with casts and molds of gastropods and bivalves. The sandstone is glauconite-rich and bioturbated. Some sandstone boulders have crossbedding and burrowing, but correct orientation cannot be determined because the rocks are out of place. One bed is visible on the surface and indicates that the erosion has not moved the rocks very far.

Figure 6. Picture of Site 1 outcrop. This is the exposure where samples of the Tallahatta Formation were collected at the Johnson property. The site is overgrown by vegetation and partially covered by eroded red mud from the above Winona Formation (images taken January 2018).

Site 2: Winona Formation

The formation identified at Site 2 (Figure 1) is the Winona Formation. This area is exposed within a ditch along a moderately steep gravel driveway. This small exposure (Figure 7) is primarily thinly bedded sandstone with normal grading. The sandstone ranges from coarse to medium grained, is sub-angular to sub-rounded, and contains quartz, limonite, and glauconite. Winona sandstone is usually green on a fresh surface, but this area is dark red and orange due to weathering and its iron-rich matrix. Some of the beds have fining upward sequences with coarse to fine quartz grains cemented in iron-rich mud. There are also sole markings throughout the orange and brown layers; these load structures are coarse while the underlying red sand is fine. Few bivalve and gastropod casts and molds were found in the thicker beds of red sandstone. Site 2.5 has similar iron-rich glauconitic fine to coarse-grained sandstone with fossils, but the rocks are scattered due to erosion. The sandstone is present at the top of a hill; however, no beds or layers are visible. Most of the samples collected were exposed due to rain.

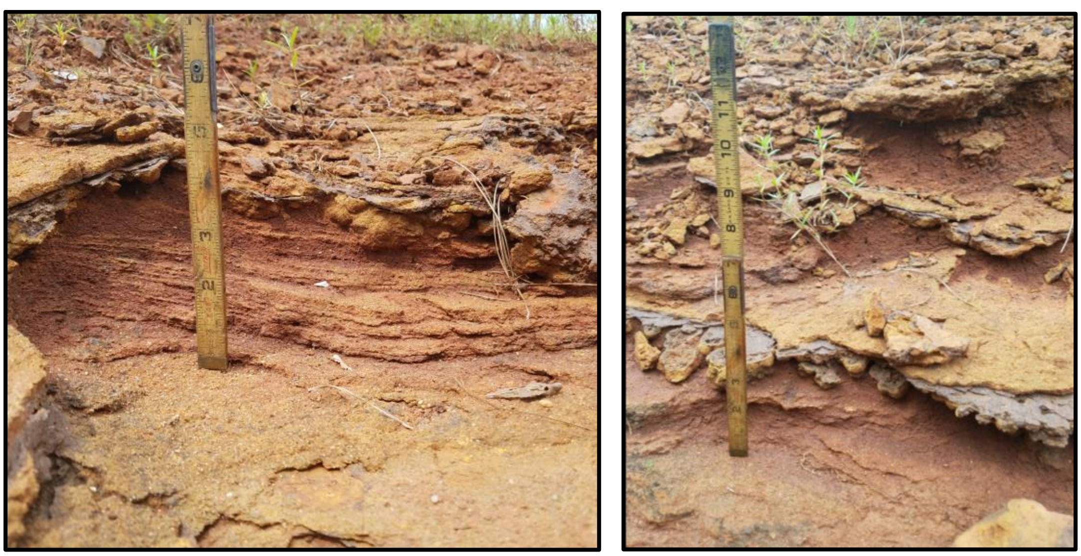


Figure 7. Picture of Site 2 Winona Formation layers. Planar cross bedding is present in the darker red-orange beds. The orange and brown layers have sole markings that are coarser than the underlying fine sediment; these are likely load structures. (Pictures taken 7/11/2018)

Site 3: Tallahatta and Winona formations

Both the Tallahatta and Winona formations were identified at this location. These units were observed walking up the driveway at which the units are exposed. Unit 1 is unconsolidated light olive-green fine-grained clay and is approximately 1 foot thick. Unit 2 is burrowed sandstone that is fine grained; the unit is 7.5 feet of *Glossifungites* ichnofacies (*Thalassinoides*) and *Skolithos* ichnofacies (Figure 8). Unit 3 is dark red

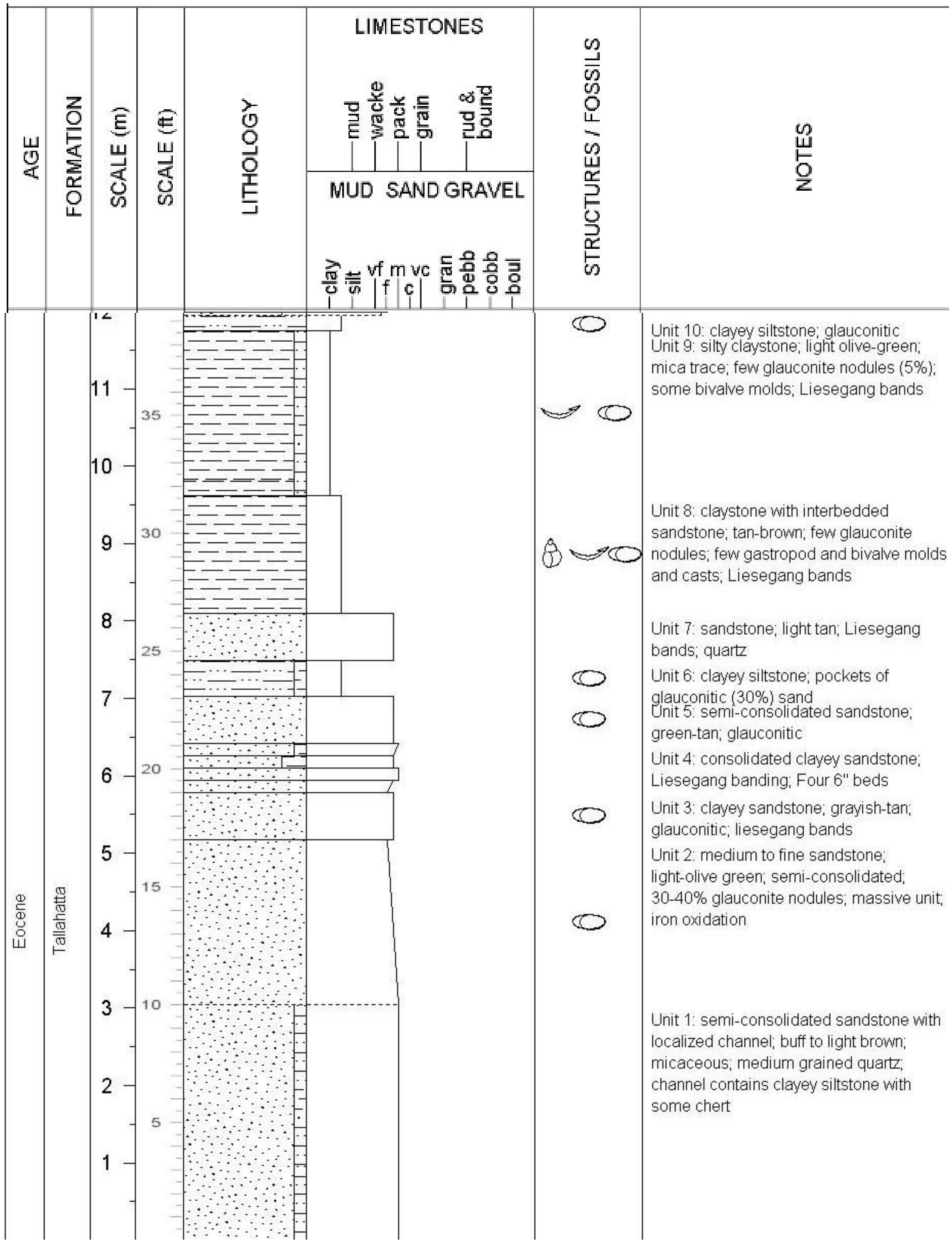
Figure 8. Image of Tallahatta Formation ichnofacies at Site 3. *Skolithos* and *Thalassinoides* burrows found in Unit 2 in the driveway exposure. The burrows are the most visible at the top and bottom right corner of the image. Image taken 02/03/19.

sandstone with lens of olive-green clay; some of the claystone is thinly bedded, and the unit is approximately 2 feet thick. Unit 4 is red sandy claystone; the sand is fine-grained, and the unit is approximately 3.5 feet thick. Unit 5 is semi-consolidated fine to medium-grained red sandstone with an iron-rich matrix that is 4 feet thick. Unit 6 is dark red iron-rich clayey sandstone interbedded with laminated clay (Figure 9); the clay is light

Figure 9. Winona Formation sandstone with clay laminae at Site 3. This is Unit 6 exposed from rainwater and erosion. The ruler on the left is 15.2 cm (6 in) long; a standard rock hammer (11 in long) is shown for scale on the right image. These images were taken 02/03/19.

olive green and ranges from 3 to 5 mm (0.12 to 0.20 in) thickness. Unit 6 is approximately 4 feet thick. Unit 7 is semi-consolidated medium-grained red sandstone with molds and casts of bivalves and gastropods. Unit 7 is approximately 16 feet thick and contains alternating layers of coarse to fine red-orange sandstone. All the units are variably glauconitic with mostly poor sorting. Units 1 and 2 are the Tallahatta Formation, and Units 3-7 are the Winona Formation.

Site 4: Bogue Statineau Road



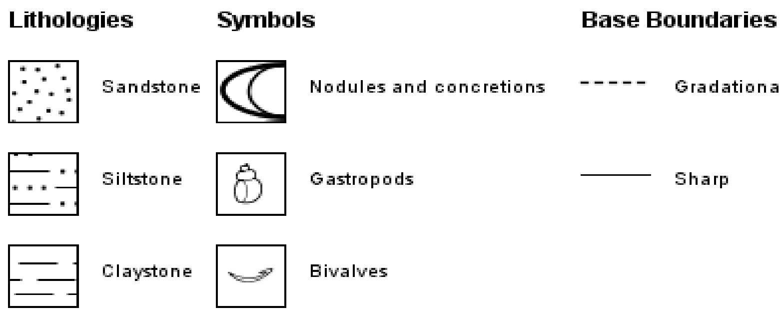


Figure 10. Stratigraphic column of Site 4 Units 1-10. Data were collected on November 10, 2018 and February 1, 2019. Lithology and symbols are shown at the bottom of the figure.

Unit 1 is a semi-consolidated sandstone with a localized channel in part of the exposure. The unit color is buff to light brown on fresh surfaces and white where weathered. The sandstone is well-sorted, sub-rounded, medium grained, and slightly micaceous; the unit is sub-horizontal with thin gray clay beds but otherwise massive. Liesegang banding is present in rings and bands throughout the unit (Figure 2). The channel has an indistinct boundary with the unit. The rock is white, very fine grained, crumbly, and has very fine mica. The clasts within the channel are mostly clayey siltstone with some pieces containing chert. The unit is approximately 10 feet (3.05 meters) thick (Figure 10).

Unit 2 is a light-olive green sandstone. The sandstone is medium to fine grained, sub-angular to sub-rounded, glauconitic, and semi-consolidated. Glauconite composes 30-40% of the sample and is fine grained. The unit is mostly massive with iron-banding and is approximately 7 feet (2.13 meters) thick.

Unit 3 is a grayish-tan, clay-cemented sandstone. The sandstone is fine to medium grained, sub-angular to sub-rounded, moderately sorted, and glauconitic with orange staining. Glauconite is black to dark green and medium grained; Liesegang banding is present throughout the unit. The unit is approximately 2 feet (0.61 meters) thick.

Unit 4 is grouped into four six-inch subunits (approximately 0.61 meter or 2 feet thick). Subunit A is clayey sandstone with fine to medium grained, sub-angular quartz, mica, and glauconite (20%). Subunit B has the same composition but is more consolidated rock than subunit A. Subunit C is clayey sandstone with fine to medium, sub-angular quartz, mica, and few glauconite nodules. Subunit D has the same composition but is more consolidated than subunit C. All subunits exhibit Liesegang banding, but subunit D has the most visible staining.

Unit 5 is greenish-tan semi-consolidated sandstone. The sandstone is sub-rounded to sub-angular, fine to medium grained, and glauconitic. Glauconite is dark green, medium grained, and rounded. The unit is approximately 2 feet (0.61 meter) thick.

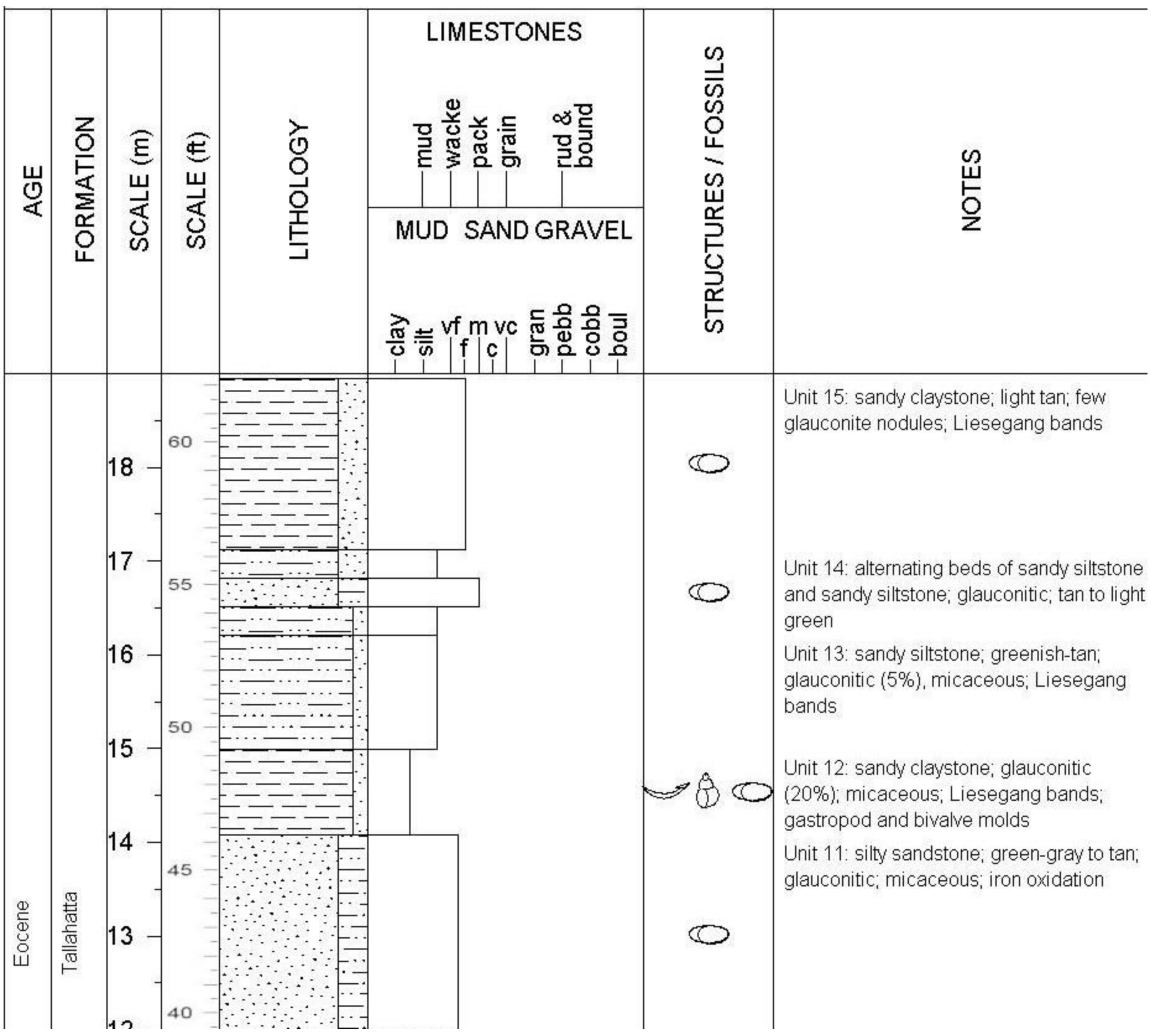
Unit 6 is grayish tan to green consolidated clayey siltstone with pockets of sand. The unit has orange-red staining and lacks glauconite. The sand is confined to cylindrical pockets and is medium to coarse grained and glauconitic; glauconite composes 30% of the sand and is medium grained. The unit is approximately 1.5 feet (0.46 meter) thick.

Unit 7 is light tan semi-consolidated sandstone with Liesegang banding. The sandstone is primarily quartz with no glauconite; quartz is fine to medium grained and sub-rounded. The Liesegang banding parallels the fractures. The unit is approximately 2 feet (0.61 meter) thick.

Unit 8 is tan-brown claystone with interbedded sandstone. The sandstone is fine grained, sub-angular, and moderately sorted with very few glauconite nodules. Gastropod molds and casts around 1 mm (0.39 in) and bivalve molds are present within the unit. Liesegang banding is parallel to fractures throughout the unit and somewhat perpendicular to the bedding planes. The unit is approximately 5 feet (1.52 meters) thick.

Unit 9 is light olive-green silty claystone. The unit is tan-white when dry; it has mica trace and few glauconite nodules are present (5-10%). The unit is compact and breakable; it has more fractures than Unit 8 and has bivalve molds (1-3 mm or 0.039-0.118 in). It is hard to tell if fissility is caused by Liesegang banding in fractures or if the rock is primarily shale. The unit is approximately 7 feet (2.13 meters) thick.

Unit 10 is compact buhrstone; it is primarily fine-grained clayey siltstone. This unit is a very resistant bed. It has sub-round to angular quartz with 50% glauconite nodules. This unit is approximately 8 inches (20.32 cm) thick.



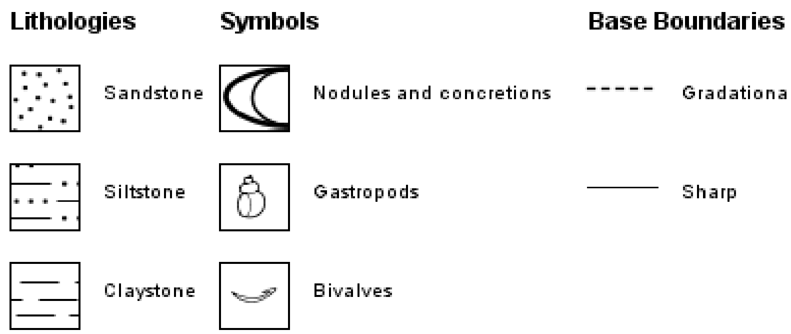


Figure 11. Stratigraphic column of Site 4 Units 11-15. Data was collected on November 10, 2018 and February 1, 2019. Lithology and symbols are shown at the bottom of the figure.

Unit 11 (Figure 11) is greenish gray-tan silty sandstone. The sandstone is very fine to fine grained quartz, sub-angular to sub-rounded, well-sorted, and glauconite and mica bearing. Glauconite and mica are very fine grained. The rock is breakable and contains orange staining. This unit was identified approximately 150 feet away from Unit 10, but lateral continuity was kept constant. The unit is approximately 7 feet (2.13 meters) thick.

Unit 12 is light gray to tan consolidated sandy claystone. The rock is moderately sorted with very fine glauconite (20%) and very fine mica. Liesegang banding parallels fractures and is visible as thick red bands where exposed. Gastropod and bivalve molds are also present and average around 5 to 10 mm (0.20 to 0.39 in). The unit is approximately 3 feet (0.91 meters) thick.

Unit 13 is greenish-tan compact sandy siltstone. The sand is fine grained, sub-rounded, glauconitic, and micaceous; the unit is very fine to fine grained and crumbly. Fine-grained mica composes 20% of the unit, and glauconite composes less than 5% of the unit. Dark orange Liesegang banding is present along fractures. The unit is approximately 4 feet (1.22 meters) thick.

Unit 14 consists of three one-foot thick subunits (approximately 3 feet/0.91 meters thick total). Subunits A and C are sandy shale/siltstone with fine sub-angular to sub-rounded quartz grains and few glauconite nodules. Subunit B is a silty sandstone with medium grained, round to sub-rounded quartz with 20% glauconite. Subunits A-C were grouped together because of the top and bottom beds' similarities; subunit B is likely a brief change in deposition.

Unit 15 is light tan semi-consolidated sandy claystone. Quartz is fine grained and sub-angular. Few to no glauconitic nodules are present, and Liesegang banding parallels bedding planes. This unit is approximately 6 feet (1.83 meters) thick to the ground surface at the top of the hill. Burrows are present in large boulders directly above this unit; they are not in place.

4.2 Structures and Fossils

Certain structures and fossils were identified within the observed units from the Tallahatta Formation and the Winona Formation. Bivalve and gastropod casts and molds were found within the Tallahatta Formation (Basic City Shale Member) and Winona Formation. Both formations are heavily weathered and eroded, so preservation of the fossils is not very likely. The fossils within the Winona Formation range from approximately 5 mm to 2 cm (0.197 to 0.787 in) in width. The fossils within the Tallahatta Formation range from approximately 3 mm to 4 cm (0.118 to 1.575 in) in width. Different diagenetic structures were also observed including Liesegang banding within the fractures of the Tallahatta Formation (Figure 12 and 13). Cross-bedding and planar bedding were both observed in the Tallahatta Formation in float at Site 1 (Figure

1). Planar bedding and small hummocky cross-stratification were observed in the Winona Formation at Site 2 (Figure 1).

Figure 12. Liesegang banding samples at Site 4. Dr. Mark Puckett is shown holding samples from the Tallahatta Formation. This float was found in the ditch beside the observed roadcut. The picture was taken on 11/10/18.

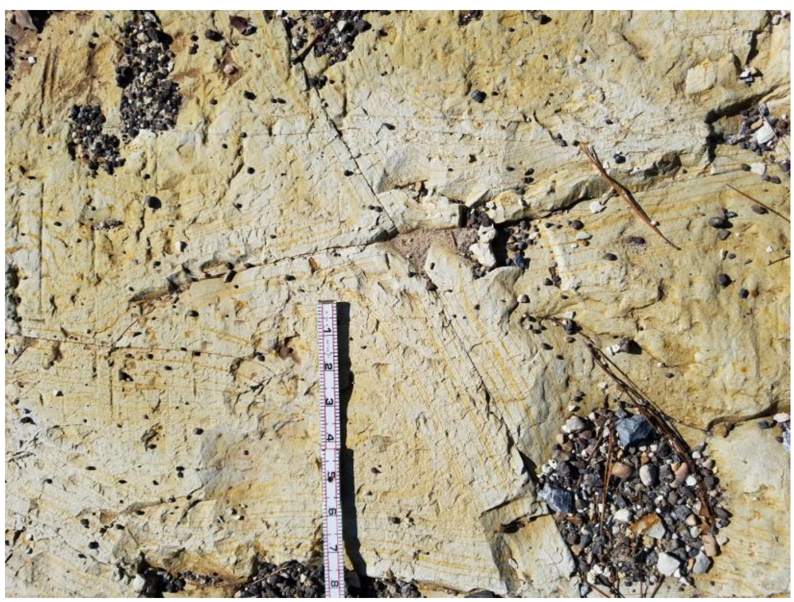


Figure 13. Liesegang banding exposure at Site 4. This unit is visible on Bogue Statineau Road and is partially covered by gravel. The measuring stick marked by inches is shown for scale. The orange banding cutting through tan claystone parallels the fractures. This picture was taken on 11/10/18.

4.2.1 Fossils:

Bivalve and gastropod casts and molds were the primary fossils found in this study. Sites 1 and 2.5 contain the most fossils within the observed units; only a few small specimens were identified at Site 4. The molds and casts were not completely intact due to weathering; when obtaining a fresh surface, more casts were exposed, but they were fragmented. Some of the samples found at the study area are shown in Figures 14-20.

Figure 14. Bivalve cast from Tallahatta Formation at Site 1. The specimen is approximately 4 cm (1.57 in) wide; it was found in sandstone float on 1/4/2018.

Figure 15. Bivalve cast from Tallahatta Formation at Site 1 (costae). The specimen measures 3 cm (1.18 in) long from beak to edge, and the costae (ribs) are visible. Image on the right was taken in the field after rain (02/12/18), and the image on the left is dry.

Figure 16. Gastropod casts from Tallahatta Formation at Site 1. The shells are at the same scale (penny for reference). The spires and whorls are intact on the left, and sutures are visible on the right image. The left image was taken July 4, 2018, and the right picture was taken February 8, 2018.

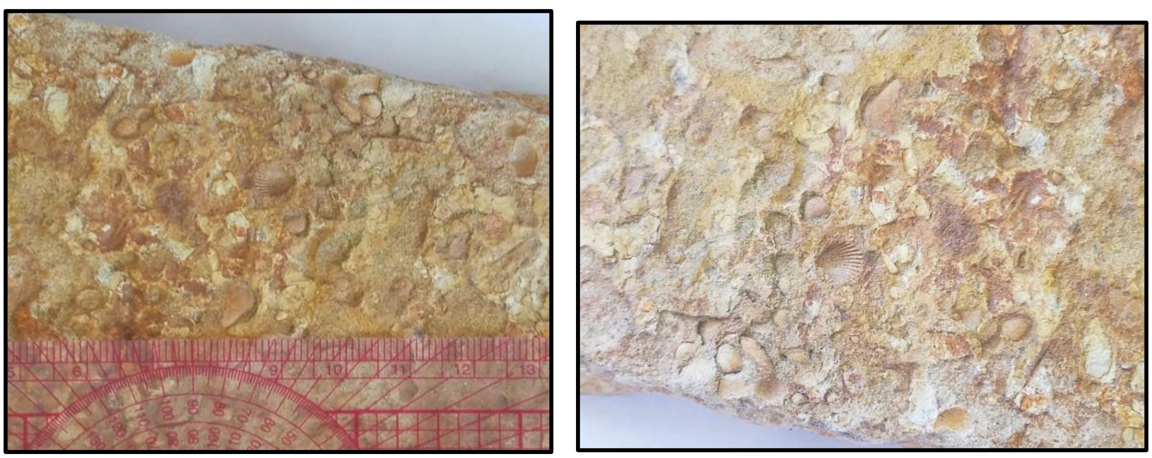


Figure 17. Bivalve and gastropod molds from Tallahatta Formation at Site 1. The sample was collected July 2018. The pink ruler is measured in centimeters (same scale in both images).

Figure 18. Possible shark tooth mold from Site 1 in Tallahatta Formation. This specimen appears to be an impression from a shark's tooth that is 5 cm (1.97 in) wide. A partial bivalve mold is at the left of the image. The specimen was found March 18, 2018.

Figure 19. Bivalve molds from Winona Formation. Specimen on the far left (Site 2.5) is approximately 17 mm (6.69 in) across; specimen on the right (Site 2) is approximately 8 mm (3.15 in) wide (penny for scale). Both shells have costa present. Both samples were collected August 2018.

Figure 20. *Turritella* cast from the Winona Formation at Site 2.5. The fossil is composed of iron-rich mud that has replaced the shell as an internal cast. It is approximately 2.5 cm (0.98 in) long and 1 cm (0.39 in) wide at the base. It was found 07/05/18.

Chapter 5: Discussion

The Tallahatta Formation and the Winona Formation were both identified at sites 1-3. The contact between them was measured at approximately 380 feet elevation using measured sections and aerial photography. At Site 4, the Winona is not observed even at 440 feet elevation at the top of the measured section on the hill. Without measured strike and dip, it is assumed that the units dip to the west given its absence. Given the thicknesses of each member, the units do not dip very steeply. The only deformation that was observed in either formation was related to diagenesis.

The Tallahatta Formation at Site 1 (Figures 1 and 6) consists of loose cobbles and boulders (float) that contain multiple shell impressions, ranging from a few mm to approximately 3 cm in size. Many rocks are fragmented and turned various orientations due to erosion of the slope. The bivalve and gastropod fossils are randomly oriented caused by natural deposition as well as storm deposits. The orientation of the shells could also be due to greater deposition of shells than sedimentation rates; high diversity and quantity of marine life in the shallow marine environment could also be a factor. There is variability of grain size within the Tallahatta Formation as well; Site 1 contains more sandstone, and Site 4 contains more claystone and siltstone. At Site 4 along Bogue Statineau Road, the Tallahatta Formation contains less fossils and more compact, fine grained siltstone and claystone.

Glauconite can be tracked through the units to determine changes in sea level and sedimentation rates. Glauconite concentrations are higher in shallow marine environments; lower concentrations indicate either a change in ocean depth or an increase in sedimentation rates. In the units where glauconite is nearly non-existent and bedding is thin, it can be inferred that a transgression occurred deepening the area underwater. In larger units, glauconite concentrations can be used to track sequence stratigraphy. Spatial distribution, maturity, and sediment source (allochthonous vs autochthonous) must be known to accurately use this method for identifying sequences (Amorosi, 1995). Future research on larger outcrops with large samples could be done to analyze certain stratigraphic sequences. In Mississippi, Interstate-20 would be the best location, but permissions must be granted before research can begin.

Liesegang banding was observed throughout many units of the Tallahatta Formation. These patterns are generally common in porous sandstone. The bands and waves form through a precipitation process that occurs during diagenesis; a chemical reaction that occurs after deposition causes bands to form within the rock layers (Racz, 1999). The precipitation likely occurs during fracturing of the rock. This would explain why the bands parallel fractures in the Tallahatta Formation. The fractures in the rock allow the solution to travel through the layers.

Storm deposits were observed in the Winona and Tallahatta Formations. Float from Site 1 has features characteristic of storm deposits, including fining upward sequences and massive deposits of shells. The Winona Formation at site 2 contains layers that are fining upward; there are coarse sole structures deposited over finer sediment. Minor hummocky cross-stratification was also observed in some of the larger beds; hummocky cross stratification is also found in storm deposits (Nnaji, 2015). Storm deposition is indicated by thin laminations of coarse, angular sand in otherwise finer sediments. At Site 2.5, the orientation of the bivalves and gastropods also indicate storm deposits. Storm deposits are characterized by massive sandstone beds that are enriched with shell debris, shells, and fining-upward sequences. Storm deposits have less mud content than tsunami deposits. Sandstone that is rippled, cross-bedded, cross-laminated, graded, and primarily sand is classified as storm deposits (Sakuna-Schwartz et al., 2015). Fining-upward sequences are generally formed by suspension and scouring; whole fossils are normally preserved in storm deposits as well (Kreisa, 1981).

The structures and fossils support the Tallahatta Formation being deposited in a shallow marine environment; the vertical burrows and other bioturbation also support this conclusion. The bivalves and gastropods were not properly identified due to a lack of preserved distinguishing features like teeth and muscle scars. For future research, better preserved samples would be needed. To properly search for and analyze fossils, samples need to be taken at a larger scale to ensure that intact specimens are discovered that are appropriate for analysis. This study on the molds and casts has potential for someone with more expertise on shell impressions. Gaining a better understanding of which specific organisms could survive could further help identify the varying sub-environments where Tallahatta Formation and Winona Formation deposited.

Microfauna can only survive in certain environments, and their presence aids stratigraphic and paleontological studies. In some of these units at Sites 1-3, it was observed that certain organisms could have thrived given the number of shell impressions; however, they were not preserved. The best method to improve the chances of finding preserved specimens is to conduct work similar to that performed by Bybell and Gibson (1985) and look for fresh calcareous samples in recent outcrops and cores. Future sampling should be carried out with a larger number of samples and from units that can be broken down. Some aspects of this research could have been improved with the help of a graduate student with more advanced geology knowledge. More nearby areas should be surveyed, including getting permission from the locals for studying an outcrop on private property instead of being limited to minor outcrops on old backroads. Interstate 20 would be a good place to correlate stratigraphic columns to Lauderdale County, as well as west of Meridian and Old Highway 80.

Possible Error and Variability

- Sites 1, 2, and 2.5 are located on property that is used as farmland (Figure 1); some areas of the land were altered to improve it agriculturally. By the end of the study, Site 1 was reworked and covered with hay to combat erosion. Site 2 was partially destroyed due to landscaping and the addition of gravel for the driveway. Site 2.5 is relatively unkept and overgrown, but the area has been cleared for farming and hunting in the past. This knowledge is based on firsthand experience because the property is owned by my family.
- Site 3 is not always accessible due to it being privately owned and managed by multiple people; the land has been leased for hunting, and the timber was cut and sold a few years ago.
- Site 4 is a roadcut that cuts through hunting property. During the study, the ditches were extended and deepened by the county; some of the units in the exposure and the units in the road were partially covered (Figure 4).
- Termites were discovered in the lab during the sample sifting process. This limited the time spent in the lab, and some of the samples were only partially picked. Most of the fossils found were not cataloged due to this problem. Many of the samples were fragile and were fragmented during the sifting process.

Chapter 6: Conclusions

For this research, rock outcrops and exposures were analyzed within the Duffee Quadrangle in Newton and Lauderdale counties; samples were collected, analyzed and interpreted to identify the formations and depositional environments. The data from this study are supported by and contribute to the interpretations and analysis of previous works.

The Tallahatta Formation consists of bioturbated glauconitic claystone, siltstone, and sandstone. The sandstone is more micaceous and fossiliferous at Site 1. Site 3 and Site 4 contain more claystone and siltstone and less fossils. Glauconite content varies in Tallahatta silty claystone because of alternating depths based on change in sea level paired with increased or decreased organic content. Glauconite distribution can be analyzed throughout different units to track changes in sequence stratigraphy in future studies. Some of the units within the Winona Formation and Tallahatta Formation were deposited, in part, as storm deposits; the fining upward sequences, as well as the fossil orientations support this idea (Kreisa, 1981).

The identified units of the Tallahatta Formation and the Winona Formation both contained various small gastropod and bivalve casts and molds. Weathering and diagenesis prevented the preservation of intact fossils. Fresh samples from the subsurface have the greatest chance of containing preserved fossils. While the rock type and fossil content vary, the ichnofacies remains the same. *Skolithos* and *Thalassinoides* (Savrda et al. 2010) were identified at the upper units of the Tallahatta Formation in the Basic City Shale. Future work should be conducted on macrofaunal assemblages in siliciclastic and carbonaceous units. This should include the sandstone and siltstone units as well as the claystone; larger samples would increase the chance of macrofauna and microfauna discovery. The correlation of well logs and core samples across Mississippi and Alabama would be important for future studies in lithostratigraphy and biostratigraphy.

This research analyzed sedimentary characteristics of known shallow marine formations to gain a better understanding of the depositional environment. A large compilation of data is important to interpret past environments to compare them to today's processes. Shallow marine environments are important to study to analyze fossil assemblages that correlate to its climate; organisms live and die based on what changes in the environment they can survive or thrive in. Roadcuts compromise many of the studied outcrops around the state of Mississippi. As years pass, overgrowth and erosion cover and degrade these exposures. Current studies while the rocks are still visible are vital. Many outcrops and exposures are overlooked due to location and accessibility; however, these studies are valuable to analyze variability of lithology and biostratigraphy within units.

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