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Crabs from the Cane River Formation of Northern Louisiana: A study of Neozanthopsis americana and associated fauna

Katie Mclain

CRABS FROM THE CANE RIVER FORMATION OF NORTHERN LOUISIANA:

A STUDY OF *NEOZANTHOPSIS AMERICANA* AND ASSOCIATED FAUNA

By

Katie E. McLain

A thesis submitted to the faculty of The University of Mississippi in partial fulfillment of the requirements of the Sally McDonnell Barksdale Honors College.

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Approved by

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Advisor: Louis Zachos

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Reader: Jennifer Gifford

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Reader: Greg Easson

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ABSTRACT

Neozanthopsis Americana is a crab from the middle Eocene Claiborne Group that lived along the Gulf of Mexico, and has been documented in Texas and Louisiana. This species was discovered by Rathburn (1928) and was later amended and added to by Schweitzer (2014). The specimens in this paper are found near Natchitoches, Louisiana, and along with their accompanying fossils are used to describe the depositional environment of the locality. Sediments were taken from the site and analyzed under a standard microscope for microfossils, which were collected and further analyzed under scanning electron microscope. In addition to the microfossils, the cuticles from six crab specimens were also examined under the scanning electron microscope. Many foraminifera were collected, and along with morphological features of the crab and associated macrofauna, a depositional environment was described. The site was probably on the edge of the inner shelf in a biostrome environment. This location would have been mechanically active and connected to the ocean, and likely was a molting/breeding ground for the crabs.

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INTRODUCTION

The brachyuran crab *Neozanthopsis americana* (Rathburn, 1928) is not well studied in literature, likely due to its sparse occurrence. The species has been documented in Northern Louisiana (Schweitzer, et. Al., 2014) and East Texas (Stenzel, 1934). While the morphology of *N. americana* has been adequately studied, the depositional environment and fauna associated with the species have not been described. The specimens used in this study were donated by the author and Guy McLain from a private collection of over 400 specimens. The specimens were cleaned and prepared so the study could be completed. A variety of fossils found alongside the crabs have been used to expand on the depositional environment. This study will focus on the general morphology of the crab, the various associated fossils, and a study of the specimens and associated microfossils under a scanning electron microscope.

METHODS AND MATERIALS

The fossils used for this study were donated to the University of Mississippi by Guy McLain, from a small, randomly selected fraction of his personal collection. The specimens were not labeled by date, but are known to come from a single location. The collection began in 2014, and since then have been stored in dry storage bins. After collection, some of the samples were washed under water and laid out to dry before being wrapped and stored in a semi-climate-controlled setting. Once the specimens were received by the University, they were labeled, cleaned, described, and placed in climate-controlled storage.

The fossils were prepared using a variety of methods. Since the specimens were collected from a sticky clay layer, the clay was first removed by washing the specimens gently with water. The fossils were then cleaned using a series of dental tools, tooth brushes, and other hand powered tools. The samples were placed in a small bowl of warm water and were scrubbed with a toothbrush until all soft or loose sediment was removed. Small dental tools and wooden picks were then used to remove sediment from small crevices, such as in between the pinchers of the chelids, or in the ocular cavities of the carapace. Sediment that accumulated at the bottom of the bowl was kept for later analysis. While a small portion of specimens were merely encased in mud, many were encased in solid rock. To remove the rock, an air scribe was used at a range of 40-85 hp. Using the air scribe above this range caused fracturing in the fossil surface, while use at lower amounts would not penetrate the rock surface. The air scribe allowed for a greater surface area to be revealed without damaging the specimens. Once the specimens were cleaned, they were labeled, and then stored at the University of Mississippi. Each specimen took anywhere from half an hour to four hours to clean.

Several parameters were then measured for each crab: the carapace height and width, measured at the midline; and sternite height and width, on specimens with sternites present.

In January of 2020, a field trip was made to collect sediment samples, and a new crab was found. The specimen was allowed to air dry with the rest of the sample and was photographed on site, (Plate 1.1), in its original form (Plate 1.2), and after a light cleaning with water (Plate 1.3). Seven soil samples were collected and placed into gallon Ziplock bags . A small portion of each sample was removed from their respective Ziplock bags and allowed to air dry for examination under a microscope. While describing these sediments, microfossils (foraminifera, ostracoda, and other microfauna) were collected and prepared for examination with a scanning electron microscope (SEM).

GEOLOGIC SETTING

The specimens used in this study were collected on private property off of Highway 478, outside of the city of Natchitoches, Louisiana (Figure 1). The property's owner has given permission to the donors of the specimens to collect fossils from the ditch on their property. In order to respect the privacy of the landowner, a detailed description of the exact location has not been provided. The fossils were collected from a road cut adjacent to Highway 478. This site was uncovered during the construction of the new highway. During this time, the hill experienced extreme erosion and was later covered following the highways completion. Since the specifics of the work done to the roadside are unknown, only the in situ sediment and fossils were considered for the discussion on the local stratigraphy. The area also experiences continuous erosion from a nearby drainage ditch. The sediment sample locations are shown in Figure 2

The site is a part of the informally described middle glauconitic layer of the Cane River Formation, Claiborne Group, middle Eocene (Figure 3). Although other fossils within the Cane River Formation have been described from this area, the study of decapod fossils is relatively recent (Stringer, 2003; Schweitzer, et. Al., 2014). Fossils from the Cane River Formation in northern Louisiana are quite rare since groundwater typically destroys fossils (Stringer, 2003). The Cane River is stratigraphically equivalent to the Weches Formation of Texas (Choung, 1975), but the decapod species *Neozanthopsis americana* has also been found in the slightly younger Cook Mountain Formation of Texas (Stenzel, 1934).

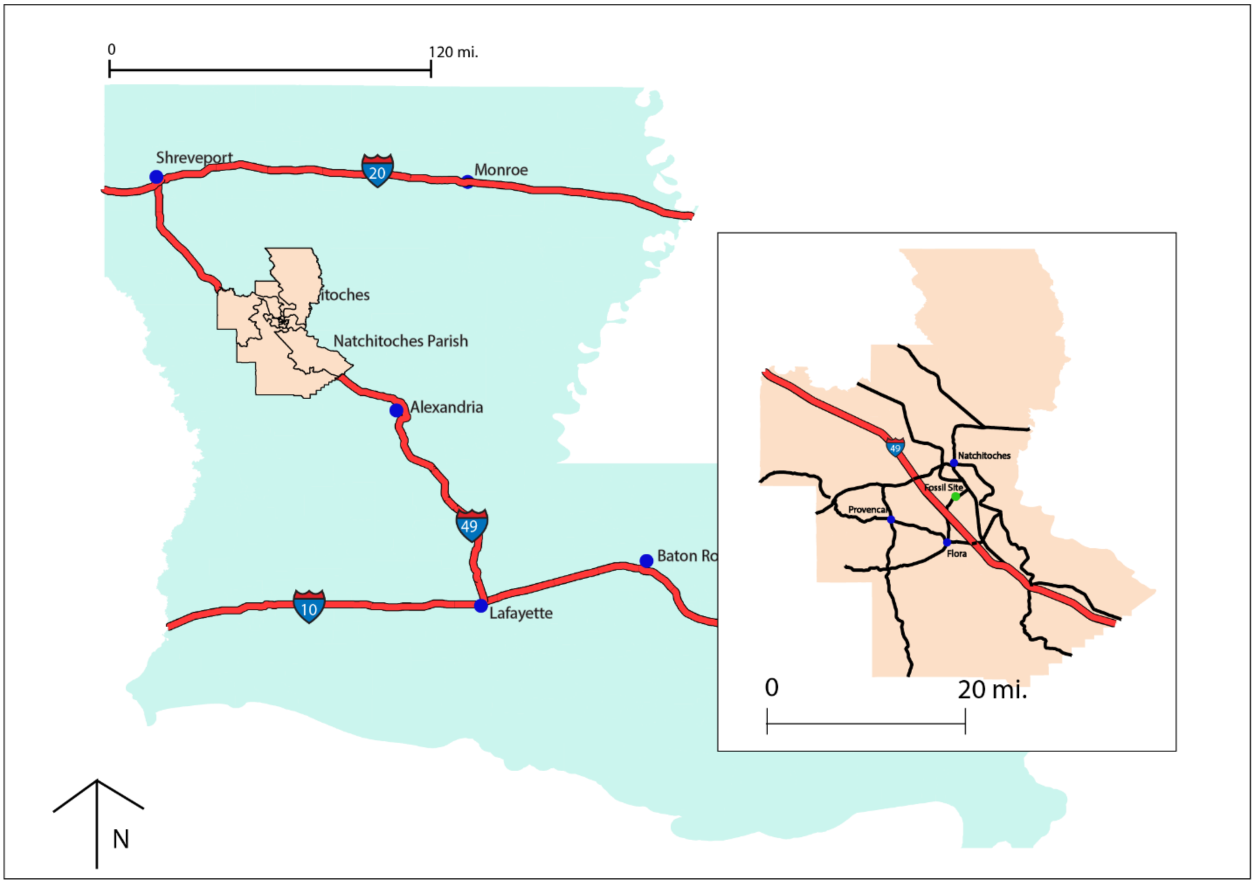

Figure 1: Map showing locality from which the fossils were collected.

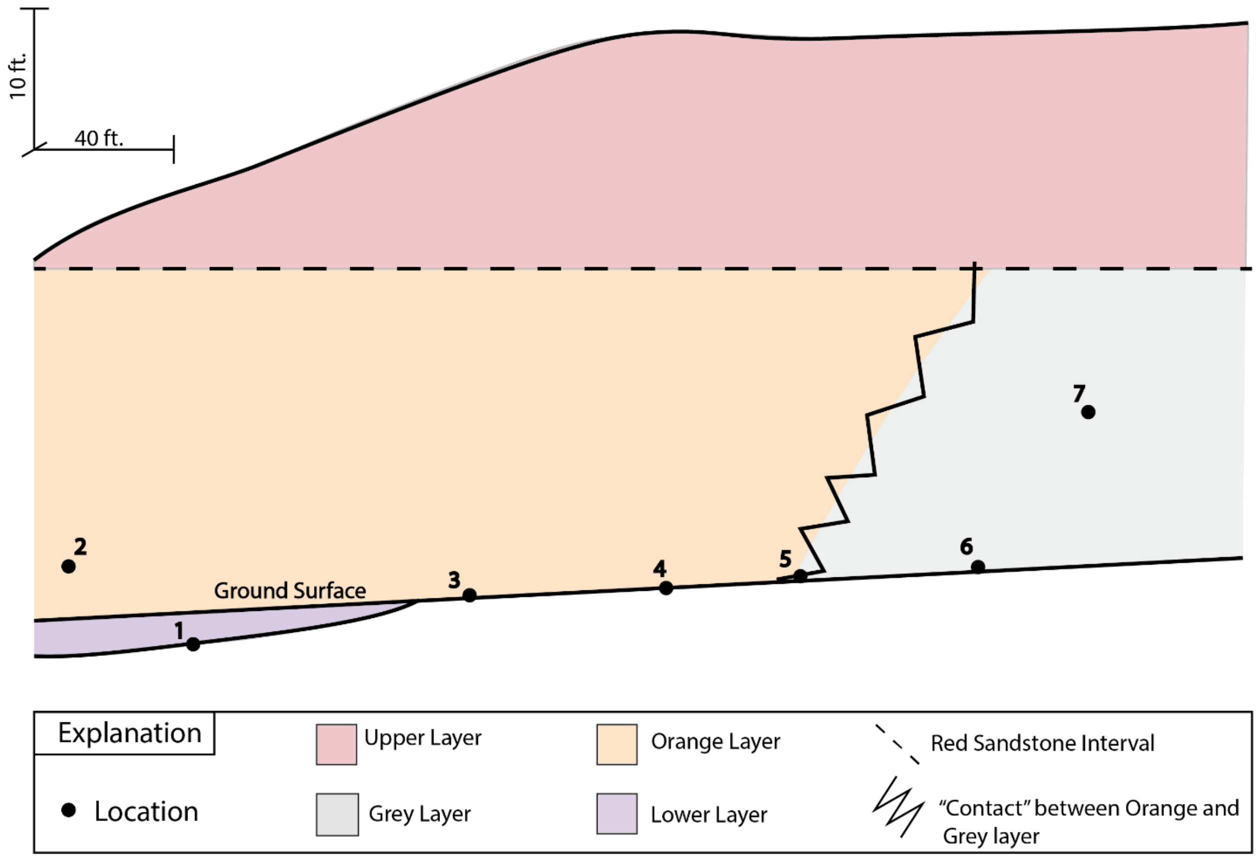

Figure 2: Map of sediment sample locations

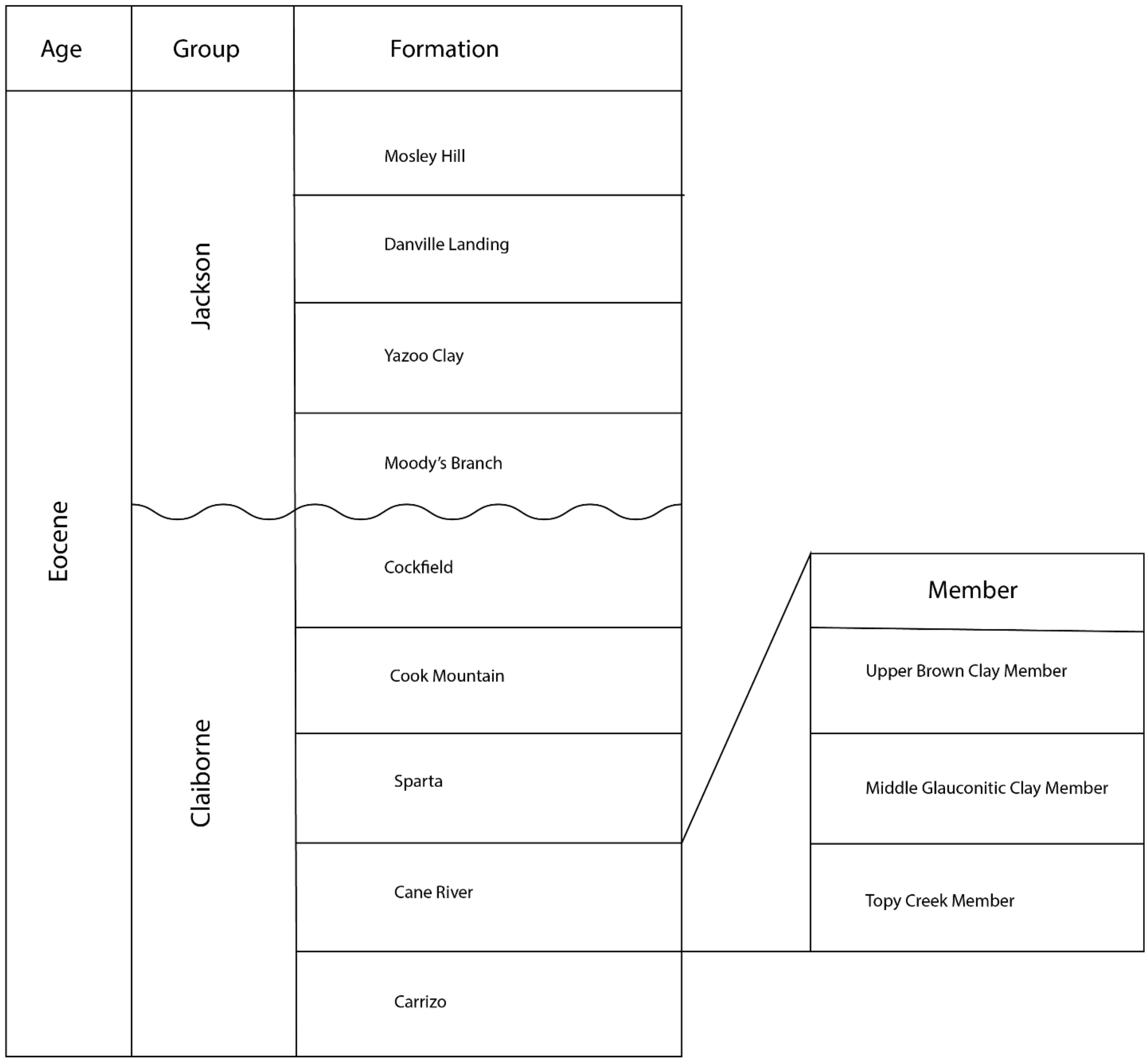

Figure 3: General Stratigraphic column of Northern Louisiana.

DESCRIPTION OF SEDIMENTS/ LOCAL GEOLOGY

1. Purplish grey to pale yellow silty clay, with some angular quartz grains present. Gypsum crystals throughout, some glauconite. Small white balls of calcareous material, roughly 1 cm in diameter. Where abundant, clay layers form in thin millimeter sheets. Appears to contain a variation of mud cracks with localized orange and red iron deposits.. Sparse microfossils. Upper layer contains 1-6 inch gypsum crystal bed. (Plate 1.4).
2. Tannish orange clay. Occasionally a loosely cemented claystone. Highly fossiliferous. No apparent bedding features. Very glauconitic. Abundant foraminifera, mostly benthic, no ostracods.
3. Dark tannish orange clay. Occasionally a loosely cemented claystone. Highly fossiliferous, with abundant foraminifera, mostly benthic with common ostracods. Very glauconitic.
4. Pale tannish orange claystone. Poorly cemented claystone, and occasionally a compacted clay. Most fossiliferous layer, with nodules present (Plate 1.5). Crab fossil and majority of bivalves found in this layer. Glauconitic; abundant foraminifera, commonly benthic, and some ostracods present. (Plate 1.6).
5. Mix of sediment from sample 4 and 6. Sparse in microfossils. Some pelagic foraminifera, and ostracods present. (Plate 2.1).
6. Pale grey silty claystone. Very fine grained. Extremely fossiliferous. Calcareous. Small pockets of iron rich sand. Glauconitic. Ostracods more common than

foraminifera, which are mostly benthic. Many small pelecypods and gastropods. (Plate 2.2).

7. Pale grey claystone. Very fine grained. Most fossiliferous "grey" area. Glauconitic. Abundant foraminifera, mostly planktonic with some benthics. Ostracods common.

The site has four distinctive layers present with unique fossil assemblages (Figure 4). Since most of the hill is covered with vegetation, an approximation of the stratigraphy is described. The bottom most layer is a dark purplish brown clay layer, blocky in texture, and has some black, non-glauconitic sediment present. The contact with the overlying unit is marked by a two to six inch band of gypsum crystals (Plate 2.3). In this layer, fossils are scarcely found, but according to the donor, a handful of shark teeth and two sand dollar echinoids have been recovered.

The next layer is a bright orange, highly fossiliferous layer. The bottom of this layer has the highest concentration of *Neozanthopsis* and large bivalves found on the whole site. Several different bivalves have been identified: *Anomia lisbonensis, Chlamys pulchricosta, Crassatellites texaltus, Crassatellites trapaquara, Cubitostrea lisbonensis, Meretrix texacola, Pholadomya claibornensis, Venericardia planicosta* (Aldrich, 1886, Aldrich & Meyer, 1886, Harris, 1919, & Lamarck, 1801). This section continues vertically for three feet before crabs and large bivalves become more sparse and other fossils become more abundant. These other fossils include various sharks' teeth, and squid guards, *Belosaepia ungula* and *Anomalopaepia jeletzki* (Yancey et. Al., 2010 & Weaver et. al., 2003), small solitary corals, and otoliths. This layer has several local feature changes, for example the middle section of the collection area (location 4) is

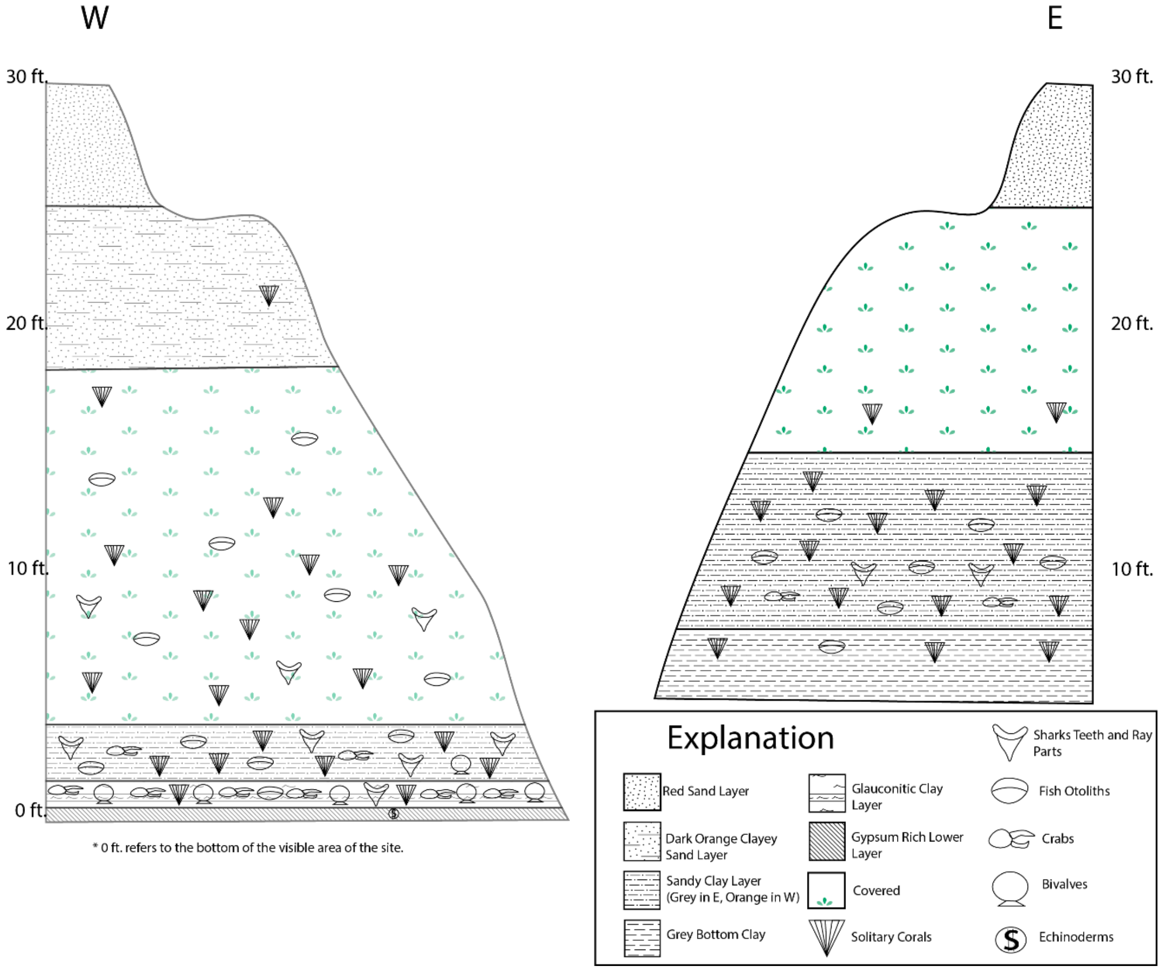

Figure 4: Stratigraphic Column showing Fossil Assemblage of the Site.

heavily compacted and produces large, well preserved crabs. Another peculiar thing is that the bottom-most section of this layer is rich in concretionary nodules, which, while they occasionally are encasing crab fossils (Plate 2.4), the specimens are so case-hardened that they cannot be recovered. The nodules primarily appear to be “empty”. Similar concretions are seen with this species (Stenzel, 1934) from the Cook Mountain Formation, and are a common form of preservation of crab fossils regardless of age or locality.

The orange layer appears to extend to the top of the hill. Fossils become sparser but much larger in size as elevation increases. Shark teeth, cuttlefish guards, and small coral fragments found here are significantly larger than similar specimens found lower in the section. The sediment also becomes enriched in iron and grades upward from the orange clay layer into a sandier red clay.

Higher on the hill, roughly 20 feet above the ditch, is a peculiar line of iron-stone approximately two to six inches thick. This layer is the only one that is confirmed to extend across the entire hill. The red stone also forms an odd erosional platform in the hill. While most of the bench is covered, there are several small outcrops that are only a few inches thick, evidence that the layer continues across the hill. The red bench located on this hill is seen on other hills in the area but is not known officially to exist anywhere else. Above this layer the sediment is exclusively a redder sand, and only holds the occasional fragile solitary coral fossil. The ironstone likely acts as a sort of groundwater “cap”, protecting the underlying fossils from chemical erosion.

On the eastern section of the hill a grey-colored sediment layer is exposed (Figure 4). The contact between the orange of the west side of the hill and the grey section has not been traced because of vegetative cover. These two layers occupy roughly the same elevation, with the grey being a few feet higher, but the grey layer extends for 150-200 feet further east before transitioning into an orange layer. The contact between these two layers is covered but is apparently located at location 5 where there is a visible mixing of the two sediment types. This grey layer is visible for 10 feet above the ditch outcrop before it is covered again. The highest outcrop of the grey layer examined (location 7) has orange sediment overlying it.

This grey layer is massively bedded and has small orange clay intraclasts less than an inch in diameter, or streaks no longer than three inches. Small shells and large solitary corals are common in this layer, but are much more brittle than the same species from the orange layer. While rare, when phosphatic fossils (teeth, bone, crab) are found in this layer they are immaculately preserved. The crabs found here tend to be encased in a more stone-like matrix, but have better preservation. These characteristics are evidence that this layer is still in a reduced environment, but has not had the same degree of carbonate dissolution from groundwater as the more highly-leached zones.

DESCRIPTION OF CRABS

Neozanthopsis americana belongs to the superfamily Carpilioidea (Ortmann, 1893), the family Zanthopsidae (Via, 1959) and is described in depth by Schweitzer, 2003. The genus *Neozanthopsis* was described by Schweiter (2003), with *Harpactocarcinus americanus* (Rathburn, 1928) designated as the type species. This genus includes *Neozanthopsis achalzica* (Bittner, 1882), *N. americana* (Rathbun, 1928), *N. bruckmanni* (von Meyer, 1862), *N. carolinensis* (Rathbun, 1935), *N. rathbunae* (Stenzel, 1934), *N. sonthofenensis* (von Meyer, 1862), and *N. tridentata* (von Meyer, 1862).

Neozanthopsis americana, originally described by Rathburn, 1928 and emended by Schweitzer 2014, has several remarkable features. However, for the purpose of this study, only general carapace features, chelid features, and sexual differences will be noted. Carapace is ovate in large specimens, and hexagonal in smaller ones, wider than long, with height being around 81% of width (Plate 3). Chelae are large and heterochelous, with large swellings on the outer surface (Schweitzer, 2014). In particular the two chelae tend to have different shapes, one more elongated and narrower, and the other strong and wide. Both typically have the same approximate length (Plate 4.1 & 4.2). Both female and male sternum are ovate.

Females have the first three sternites fused, with the fourth being concave with tall knobs near the bottom of the coxa, acting as pleonal holding mechanisms. While gonopores have been reported on sternite 6, none have been seen in this study. All female pleonal somites are free and generally ovate in nature, with the upper somites being a well-rounded wide triangular shape, and the lower being a well-rounded rectangular shape (Plate 4.3 & 4.5). The female sternum appears much larger and more rounded than male sternum.

Males have a deep Y-shaped groove between sternite 3 and 4. Sternites and overall sternum are narrower than females of the same approximate size. Upper somites are much more triangular and narrower than in females, with the lower somites having the same approximate shape as the female's (Plate 4.4 & 4.6).

Each specimen was measured for carapace width and height, sternum width and height, and labeled by sex. While most specimens were complete enough to be measured in each way, several were just partial and could not be measured. Only 30 of the 61 specimens were complete enough for sex to be determined. These measurements were used to create several charts (Figure 5- Figure 13).

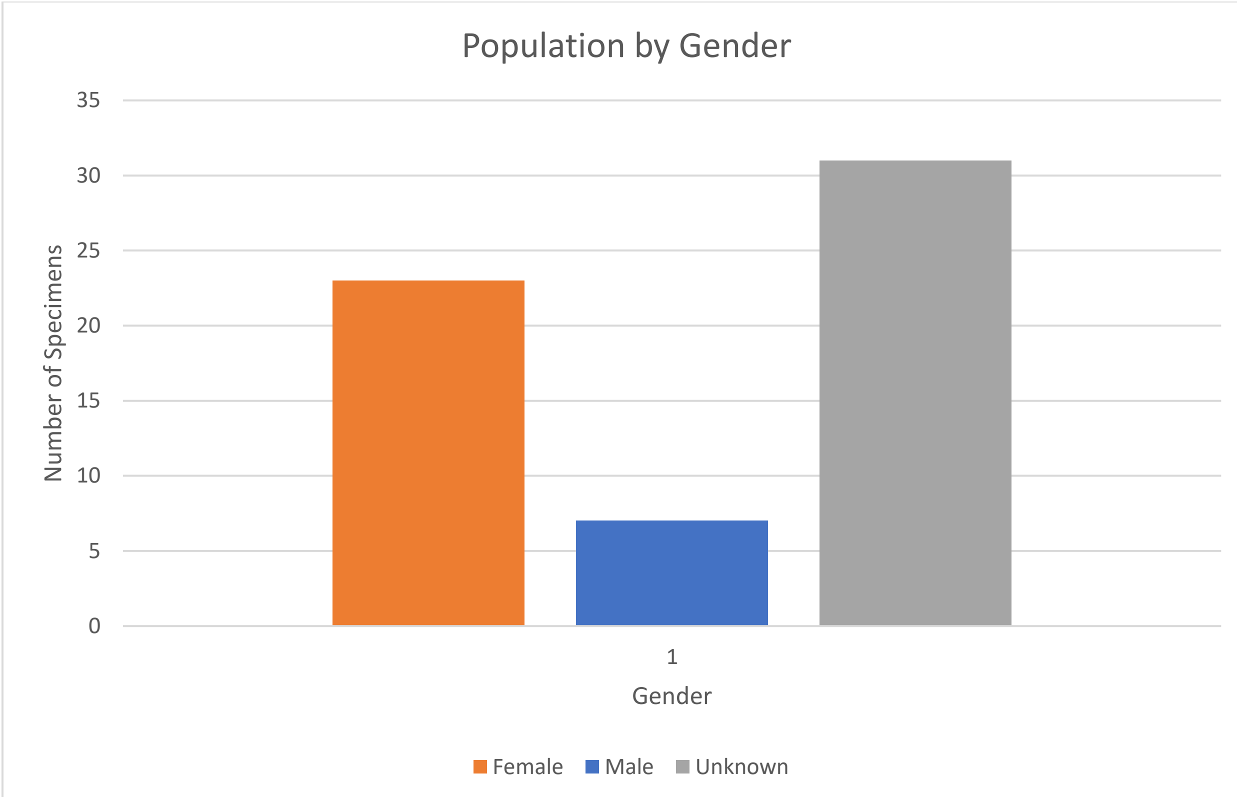

Figure 5: Graph showing population by gender. Females = 33% of population, males= 11.5%, unidentified= 50.5%. Excluding unknown, females = 77% and males = 23%.

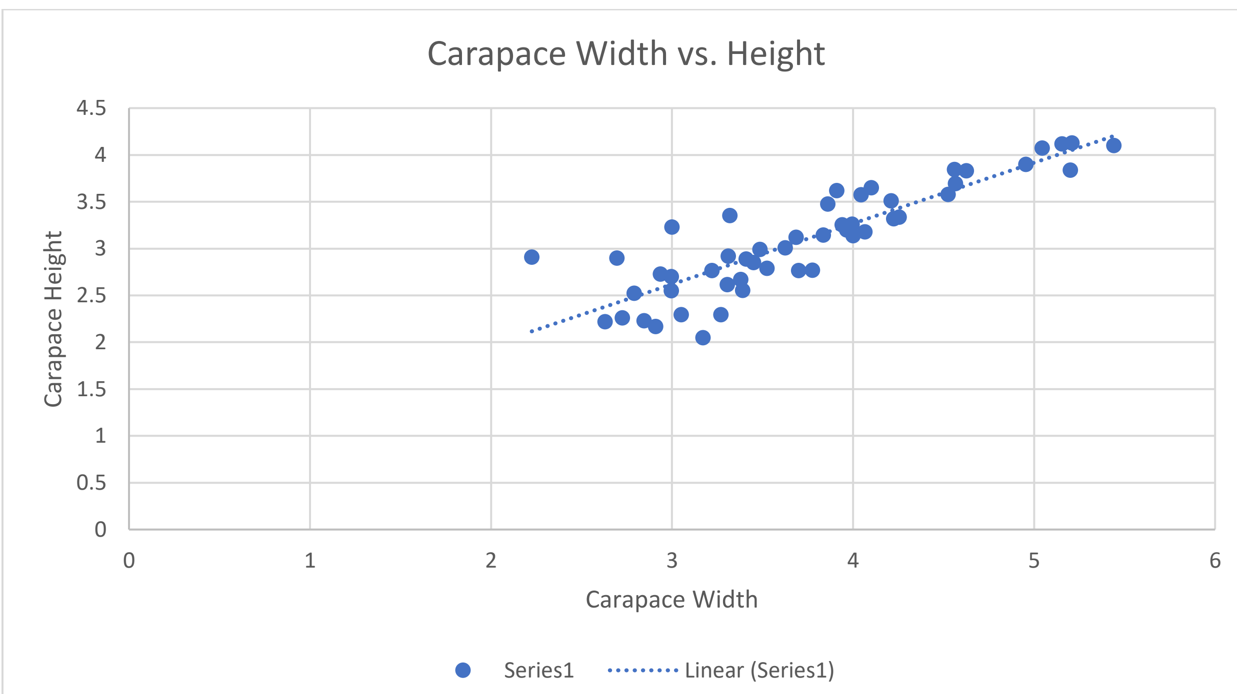

Figure 6: Graph showing 51 specimens carapace width versus carapace height. A trend line has been rendered as well.

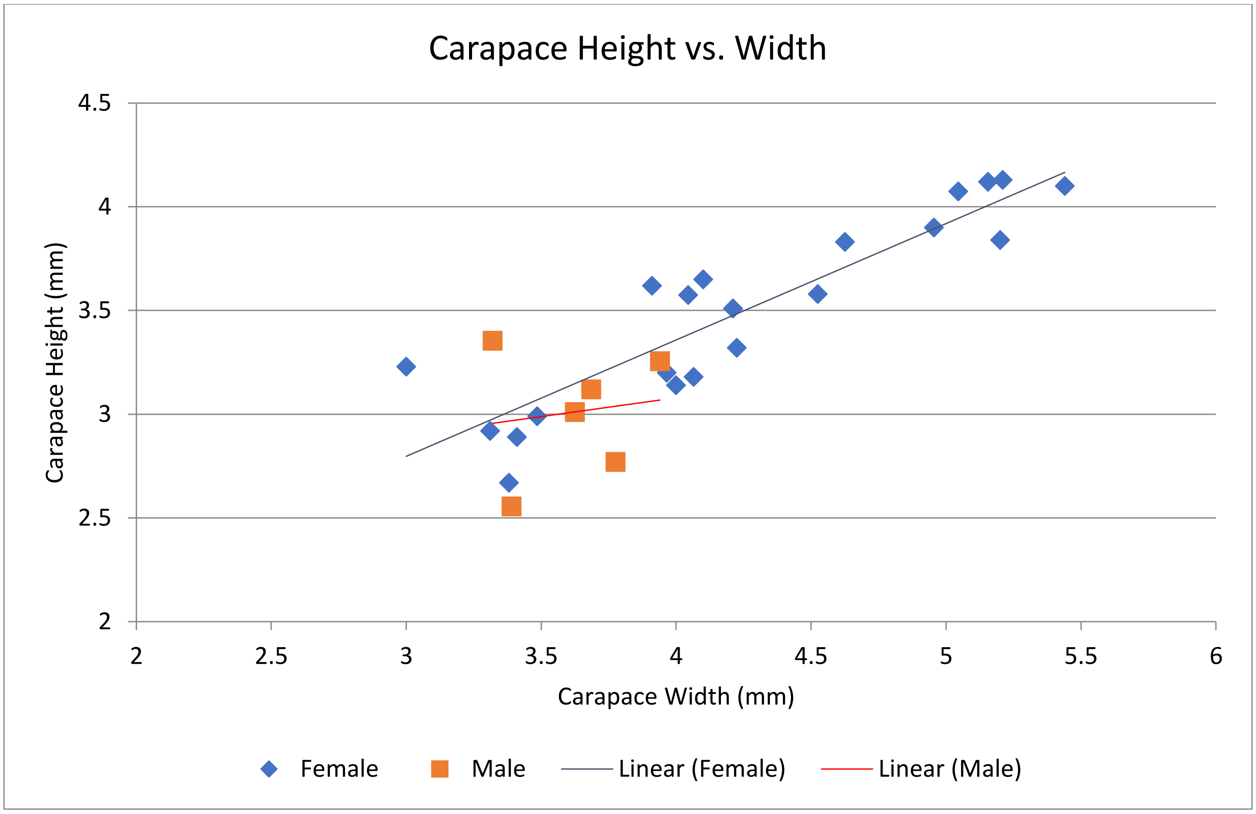

Figure 7: Graph showing carapace width versus carapace height by gender.

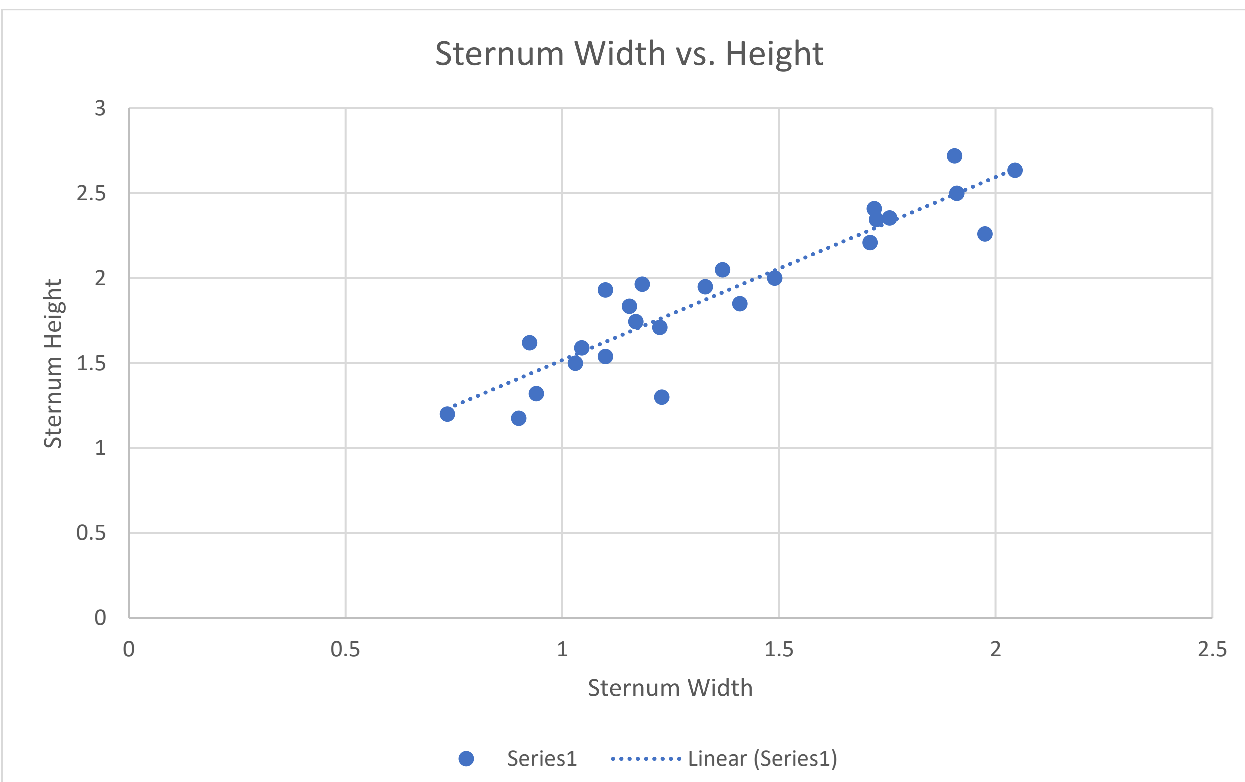

Figure 8: Graph showing sternite width versus sternite height, and associated trend line.

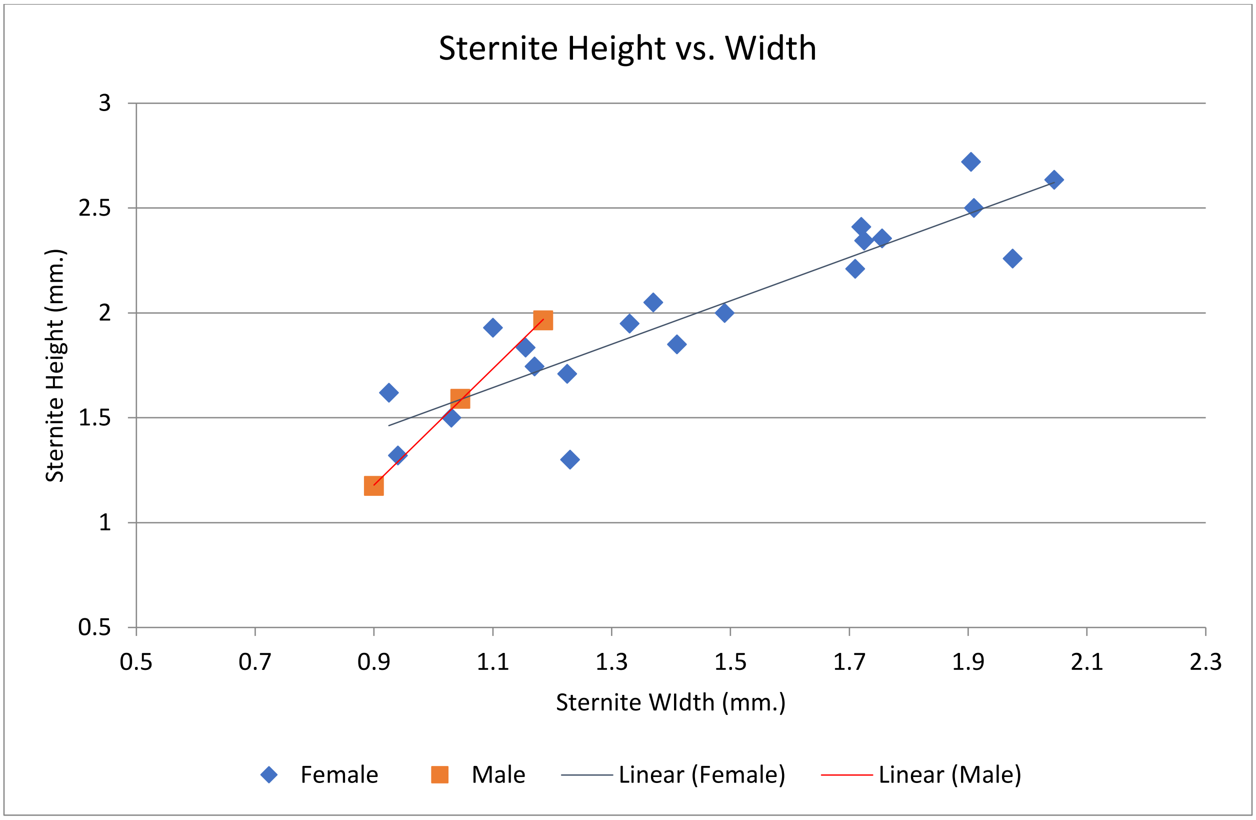

Figure 9: Graph showing sternite width versus height in males and females, with their associated trendlines.

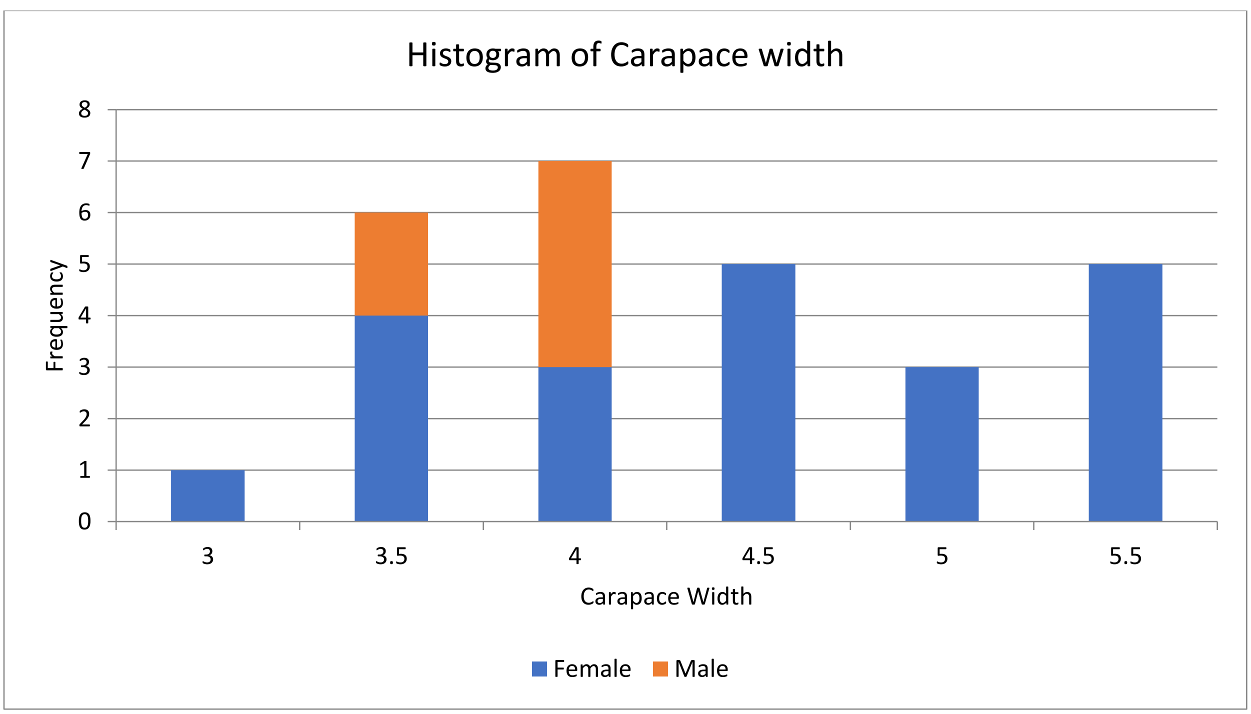

Figure 10: Histogram of carapace width, showing male and female specimens.

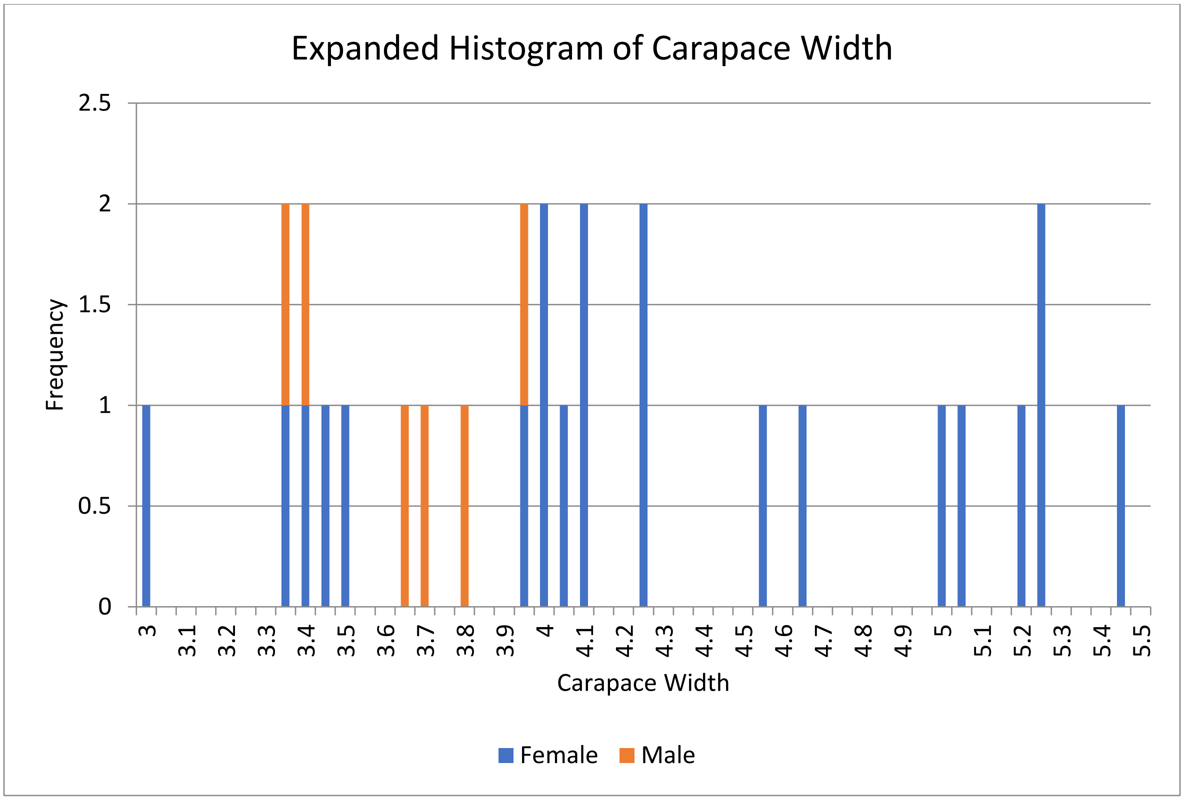

Figure 11: Expanded histogram of carapace width, showing male and female specimens.

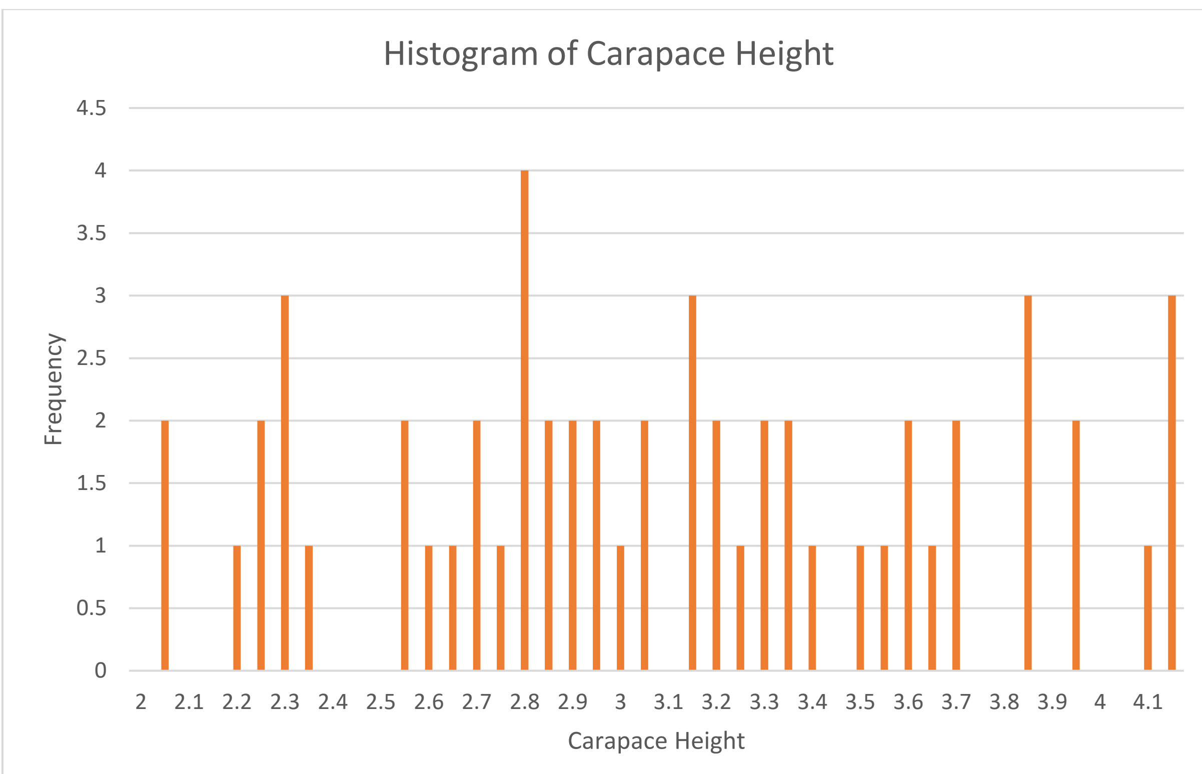

Figure 12: Histogram of carapace height.

After measurements were completed, cuticles from six specimens were collected. Using a scanning electron microscope, images were taken of the cuticle to determine what stage of the molting cycle the crabs were in. Six specimens, NA1002, NA1014, NA1031, NA1032, NA1041, & NA1050, were scanned (Plates 7 &8). In almost all images the epicuticle, endocuticle, and exocuticle are preserved and visible. Typically, this is all that is present. Underneath this layer is a much thinner layer that was not able to be harvested for scanning (Plate 5.1), that is possibly a fossilized remnant of the dermis in living crabs. In between these two layers there is usually a very small gap of free space, or a gap that had been filled with sediment, glauconite grains, or even by gypsum. The epicuticle mimics the surface features and has very noticeable bumps and valleys that form the same features that can be seen on the surface of the crab (Plate 7.3, 7.4, & 8.4). The epicuticle is built of tall erect pillars that vary in height in order to create the surface features. These pillars are shown in cross-section (Plates 7.3 & 8.1) and straight on (Plates 8.2 & 8.3).

DISCUSSION OF NEOZANTHOPSIS AMERICANA

The majority of crab fossils could not be assigned a gender (Figure 5), typically because the sternum was not present or not preserved well enough to be distinguished. However, it is important to note that out of the half of the population that was assigned a gender, there were three times as many females as there were males. In conjunction with this, the males are on the smaller end of the size range, as seen in Figure 12. This could indicate that the field site represents some sort of nursery or sanctuary for the species, which is why large male crabs would not be found here. Another possibility is that the location is a molting area. Several species of crabs can only mate just after a female has molted, which could be a possibility here.

While the species have a linear relationship between carapace width and height, larger specimens follow this trend much more than the smaller ones (Figure 6). As mentioned in the original diagnosis, the smaller specimens tend to be hexagonal rather than ovate. However, it does not appear that this hexagonal form was consistent throughout the population, with some small specimens being taller than wide, and some being the standard wider than tall. This could indicate that there is an ideal body shape for survival, and that crabs without it do not grow to be as large as those with it. While there is greater variation in male specimens (Figure 8), it is important to note that the number of male specimens is much smaller than that of the females, with only seven specimens total. The males are seen to have a different trend line, but since the sample size is so small it is not statistically significant. It appears that the few males that are present do comprise the major portion of the smaller, atypical body shapes (Figure 6).

Just as with carapace measurements, sternite size seems to grow linearly, and with slightly less variance (Figure 8). When separated by gender (Figure 9), the two lines have different slopes for sternite growth. This is expected as the female sternum is much wider than the male. Female sternites take on wide, short shapes, while the male sternites are much longer and narrower. Unfortunately, there are very few data points for male specimens, and only three of the seven exhibited enough sternum for accurate measurement.

A histogram (Figure 10) shows both a wide spread in carapace width, and also a cluster of males of only 3-4cm width, while the largest specimens are female. This was also the case for the study conducted by Schweitzer, et al. (2014). While it could be possible that the females are the larger of the genders, it seems more likely that this area simply has a large shortage of adult male crabs. The expanded histogram (Figure 11) shows several gaps in sizes. These gaps could be characteristic of molting. If the crabs molt at the same size and, presumably, age it would be reasonable for there to be gaps in carapace size for the species. Some modern crabs increase their size by 15% with every molt. Just as with carapace width histogram, the carapace height histogram (Figure 12) shows the same gaps in sizes, and also shows that the carapace height is significantly narrower than the width. Rathburn(1928) concluded that carapace height was 81% of carapace width. This data set shows that the height is 83.7% of the width.

The six specimens imaged with the SEM showed that the only layers present were the epicuticle, endocuticle and exocuticle. In crabs that are preparing to molt, the cuticle will contain doubles of these layers, with a small space in between the two sets of cuticle. It is possible that a crab in the premolt stage might only preserve its inner cuticle layer, giving the fossilized crab the appearance of being a molt, or freshly molted crab. As noted by Feldman and Schweiter (2017), one of the best ways to determine if a crab is a molt of a live species, is by their body position (i.e. appendages in strange positions, separation of the carapace). Using this method, a large portion of the crabs appear to be molts (Plate 5.2, 5.3, & 5.4). While this is not conclusive, it does support the idea that this might be some sort of breeding ground. It is important to note that of the six males present, none have the characteristics of a molt.

There are some special features about the preservation of the crabs that should be noted. On multiple crab fossils there are other attached fossils or ectobionts (Plate 5.5 & 5.6), and one crab fossil that has an otolith on its sternum (Plate 6.1). While it is unlikely that these were present during the crabs' lives, it does indicate that these carcasses were on the seafloor surface for a long time. Interestingly, a handful of the specimens have very similar missing carapace pieces (Plate 6.2 & 6.3). This could be an indication of a specific type of predation or possibly just a weak area of the carapace.

DISCUSSION OF ASSOCIATED FOSSILS AND POSSIBLE DEPOSITIONAL ENVIRONMENT

Using a low-power binocular microscope, microfossils were collected and mounted on stubs, coated with a thin layer of gold-platinum, then examined using a SEM. While some of the fossils were in pristine condition, others were slightly corroded. Several of the foraminifera and coccoliths had experienced some degree of recrystallization.

Coccolithophore nannofossils were common, and species found are (Plate 12, Plate 13):

- *Reticulofenestra daviesii*
- *Calciosolenia fossilis*
- *Reticulofenstra minuta*
- *Pocillithus spinulifer*
- *Reticulofenstra martinii*
- *Cruciplacolithus inseadus*
- *Pontosphaera* sp.
- *Coccolithus formosus*
- *Discoaster distinctus*
- *Discoaster sublodoensis*
- *Reticulofenestra hesslandii*
- *Clausicoccus fenestratus*
- *Discoaster wemmelensis*

The coccolithophores are important because they permit a precise dating of the sediments. The overlapping ranges of the species above (Figure 13). place the crab between 42 and 46.5 million years old. Overlap of confirmed ranges constrains the age to between 46-46.5 million years.

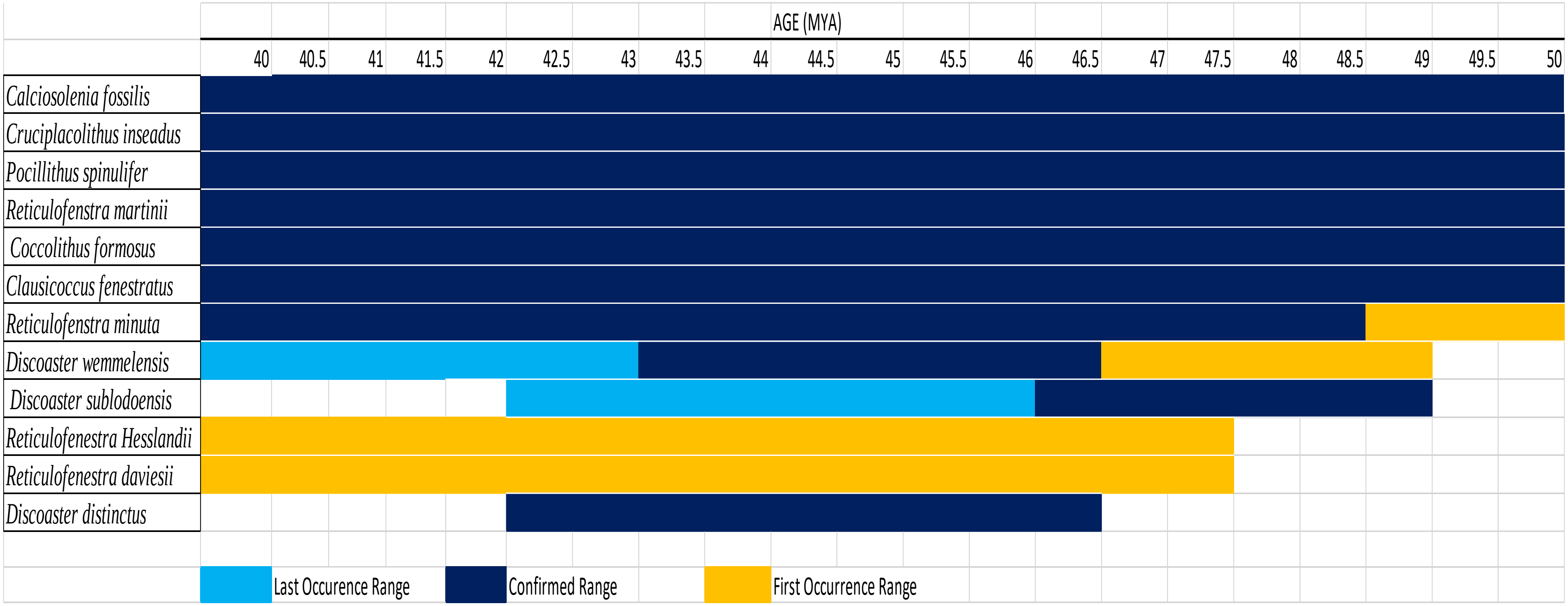

Figure 13: Chart showing age ranges of coccoliths.

The following foraminifera were found (Plate 9, Plate 10, & Plate 11):

- *Pulvinulinella bella*
- *Valvulineria gracilis*
- Several species of *Robulus*
- *Cibicides hovelli*
- *Eponidea sp.*
- *Valvulina sp.*
- *Discorbis sp.*
- *Quinqueloculina sp.*
- *Quinqueloculina striaturata*
- *Globigerina sp.*
- *Globulina sp.*
- *Blobulina ampulla*
- *Cornuspira olygogyra*
- *Boldia carinata*
- *Nodosaria affinis*
- *Cibicides submammiformis*
- *Planulina kniffeni*
- *Haplophragmoides sp.*
- *Bolivina louisiana*
- *Sigmoilina inconspicua*

Along with these foraminifera, several unidentified ostracods, a small vertebra, micro-gastropods, micro-pelecypods, and a handful of plate fragments and spines from echinoids were found.

The abundance of miliolid, and several of the individual foraminifera point to an inner neritic environment. The most common miliolid is *Quinqueloculina*, of which most species are marsh dwellers; indicating that nearshore marine environments are possible as well. Since the echinoid fossils, which are made out of chemically unstable high-magnesium calcite, were still intact but physically weathered, it is assumable that the environment of deposition was somewhat energetic. The nannofossil, *Discoaster sublodensis*, also is known to come from an inner neritic environment (Bybell, & Self-

Trail, 2007). The presences of planktonic forams is strong evidence that the depositional environment was an open oceanic environment, rather than marsh or lagoonal.

There have been several post-depositional diagenetic effects on the samples. The original environment was probably similar to the grey layer in coloration, as the orange tones come from groundwater interaction. Evidence of oxidation is found in some of the specimens from this orange layer which have iron staining (Plate 6.4). The presence of the echinoid plate fragment with preserved stereom ultra-structure in the grey layer indicates that this section has very low permeability and little interaction with groundwater. Even small amounts of acidity would have at least partially dissolved this fossil, replacing it with sparry calcite or erasing it entirely (Zachos, 2008) . The fact that broken plates and spines are preserved, along with the lack of complete sand dollars, indicate that the depositional environment was very mechanically active. Post-depositional diagenesis has also been influenced by sulfate-rich waters locally. Evidence of this water is shown by small clusters of gypsum found throughout the entire area, some specimens exhibiting small veins of gypsum crystals along their bodies, and one specimen encased entirely in gypsum (Plate 6.5). This indicates that post-deposition, this area either became highly salinated, or that calcium sulfate from the layer below was freed by groundwater and then migrated upwards where it recrystallized. Another specimen has hexagonal cracking in its carapace, an indication that the clay layer might have some expansive qualities (Plate 6.6).

The lowermost unit was likely a lagoonal type water body. The gypsum crystals throughout the dark clay, and the lack of fossils present, are indicators of a water with high salinity. The continuous gypsum layer atop the clay, around 2in thick, suggests the lagoon dried up and was then re-submerged at a later time, as the sea level began to rise again.

Based on Schweitzer's 2014 hypothesis, the depositional environment is approximately 20-50 meters deep, and tropical to subtropical. Although there are several fish otoliths and shark teeth from species that reside in much deeper waters, it is still very likely that these specimens swam inshore, rather than the other species living offshore. While a patch reef would explain the large occurrence of vertebrate species, the lack of large reef building corals negates this idea. Likely it was a biostrome, an area where there is a large amount of living creatures supporting themselves on the carcasses of other creatures, or a sort of seagrass meadow. Decapods, being notorious scavengers, would readily inhabit this type of environment, feasting on the carcasses of fish, and other large species.

CONCLUSION

The crabs found at this location were almost entirely female, with the few males present being some of the smallest specimens. This area was likely some sort of molting enclave where female crabs would travel to molt and then most likely mate with available males. Scanning electron microscope pictures confirmed the presence of a single cuticle layer in the specimens sampled. Based on the associated macro and micro-fauna, this area was connected to the open ocean, likely along the proximal edge of the inner shelf. The lack of colonial corals implies that the area must be a biostrome, rather than a biohaven, and the abundance of miliolids points to the presence of seagrass. Range analysis of the nannofossil dates the site between 46 to 46.5 million years old. The fauna here was likely exposed on the surface of the sea floor for an extended amount of time allowing for mechanical weathering and the accumulation of epibionts before being buried and fossilized. This is suggestive of a condensed section and probably represents a period of high relative sea level during the Middle Eocene.

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APPENDIX A- PLATES

Plate 1

1.1

1.2

1.3

1.4

1.5

1.6

Plate 1

1.1-*Neozanthopsis* in matrix found during field trip.

1.2-“Dirty” state of crab found on field trip.

1.3-“Clean” state of crab found on field trip

1.4-Bottom layer of site, in its full visible thickness.

1.5-Nodules found at location 5.

1.6-Image of location 5, where majority of crabs and bivalves are found.

Plate 2

2.1- Location 6 showing the mixing of the orange and gray sediments.

2.2- Grey layer as seen in location 6.

2.3- Line of gypsum crystals seen at the top the bottom layer.

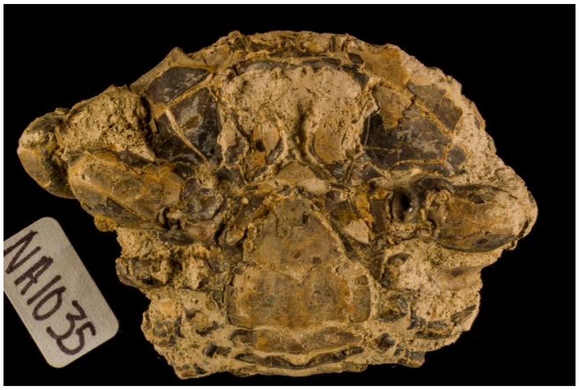
2.4- Crab encased in a nodule.

Plate 2

2.1 **2.2**

2.3 **2.4**

Plate 3



3.1

3.2

3.3

3.4

3.5

3.6

Plate 3

3.1- NA1035, View of sternum of large crab

3.2- NA1035, View of carapace of large crab

3.3-NA1035, View of orbital features of large crab

3.4-NA1035, Dorsal View of large crab

3.5-NA1010, Carapace of small crab

3.6- NA1010, Sternum of small crab

Plate 4

1.1- NA1021 large claw found without carapace.

1.2- NA1049 Specimen with two differently shaped chelids.

1.3- NA1017 Female sternite example

1.4- NA1015 Male sternite example

1.5- NA1032 Female sternite showing pleonal locking mechanisms

1.6- NA1053 Male sternum showing fusion of upper somites.

Plate 4

4.1

4.2

4.3

4.4

4.5

4.6

Plate 5

5.1

5.2

5.3

5.4

5.5

5.6

Plate 5

5.1- NA1057, Image showing cuticle used for SEM, and underlying “dermis” layer.

5.2-NA1048, Known molt: evident by the good preservation of only the carapace and large left claw which is angled unnaturally.

5.3 & 5.4- NA1050, Known molt having 1.2mm of horizontal displacement between end of carapace and bottom of sternum.

5.5-NA1015, Specimen showing shells and other small fossil particulars within the matrix that hosts the crab.

5.6-NA1023, Specimen with small bivalve attached to surface of carapace.

Plate 6

6.1-NA1041, Crab with small fish otolith just above sternum.

6.2-NA1029, Crab with peculiar “chunk” missing.

6.3-NA1013, Crab with similar features as Plate 6.2

6.4-NA1003, Crab with iron stains on carapace.

6.5-NA1024, Crab with hexagonal fractures on carapace.

6.6-NA1028, Claw encased with gypsum.

Plate 6

6.1

6.2

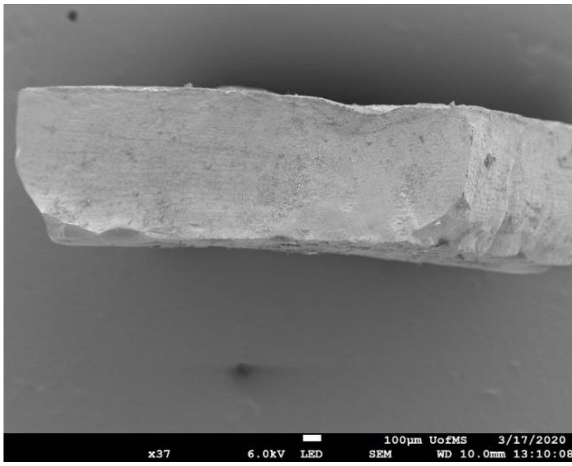
6.3

6.4

6.5

6.6

Plate 7



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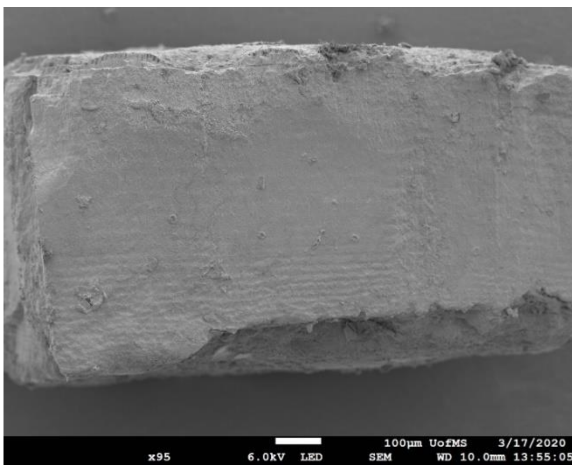
7.2



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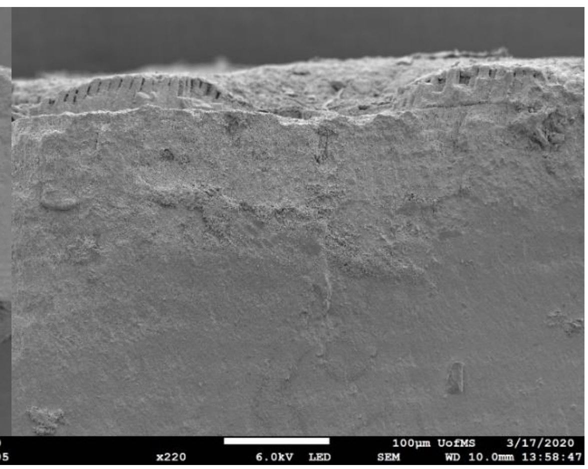

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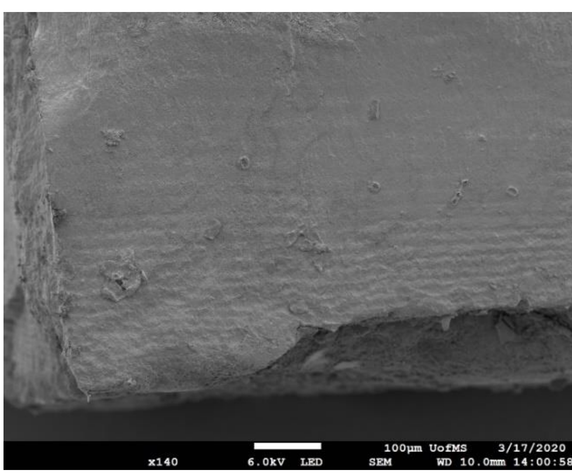

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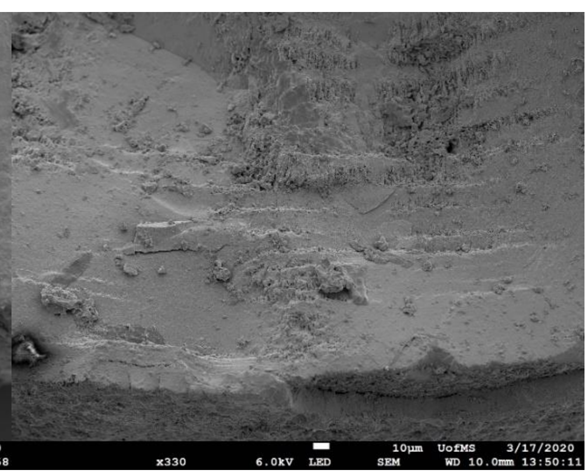


7.6

Plate 7

7.1- NA1014- Small piece of cuticle.

7.2- NA1014- Coccolith (*Reticulofenestra daviesii*) on surface of cuticle.

7.3- NA1031- Small piece of cuticle showing exocuticle, endocuticle, and epicuticle.

7.4- NA1031- Image of cuticle showing both erect pillars in the epicuticle, and showing how the "bumps" on the surface of the carapace continue below the surface.

7.5- NA1031 Image of lower cuticle.

7.6- NA1041- Image of contact between exocuticle and endocuticle.

Plate 8

8.1- NA1041- Image showing erect pillars in the epicuticle for cross section.

8.2. NA1041- Image showing erect pillars in epicuticle from the surface.

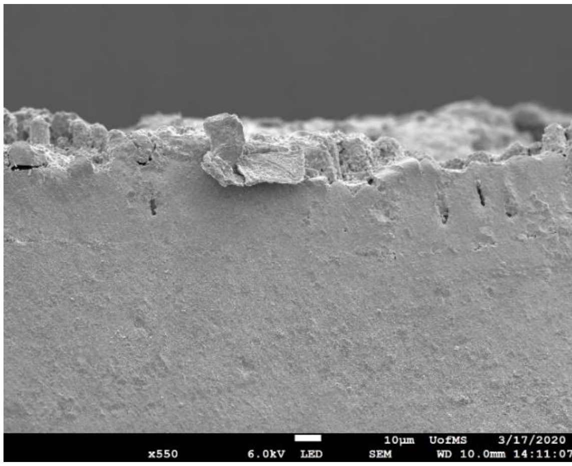
8.3- NA1041- Image showing erect pillars in epicuticle from the surface.

8.4- NA1050- Image showing the epicuticle topography and contact with endocuticle .

8.5-NA1050- Image showing texture of endocuticle.

8.6-NA1050- Image showing texture of exocuticle.

Plate 8



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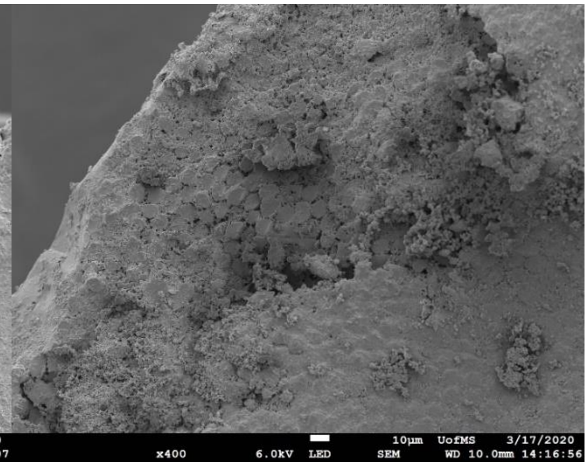

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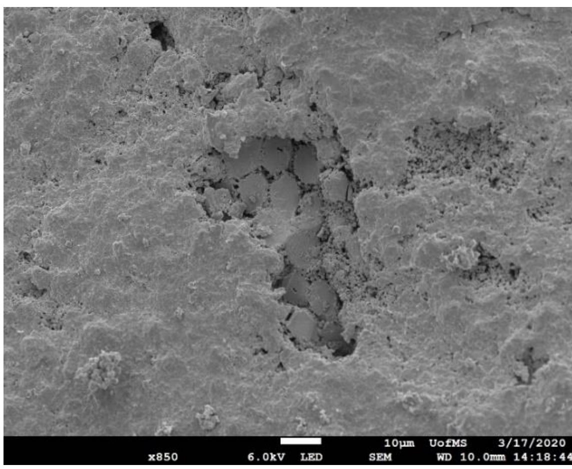

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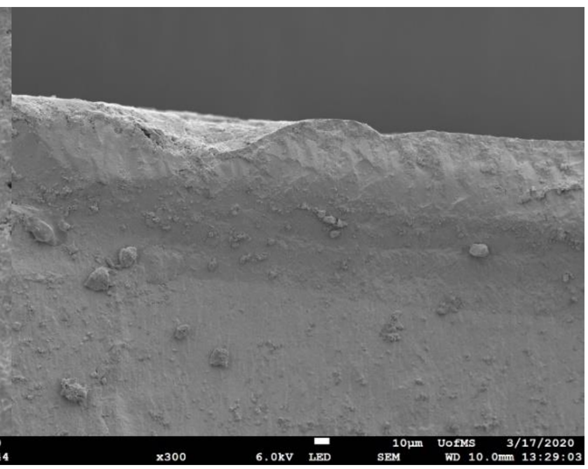

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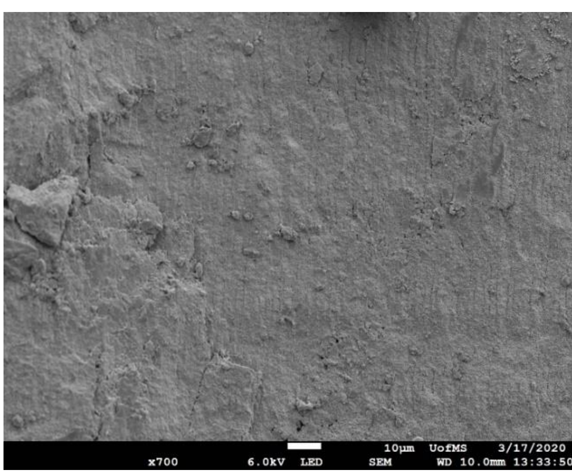

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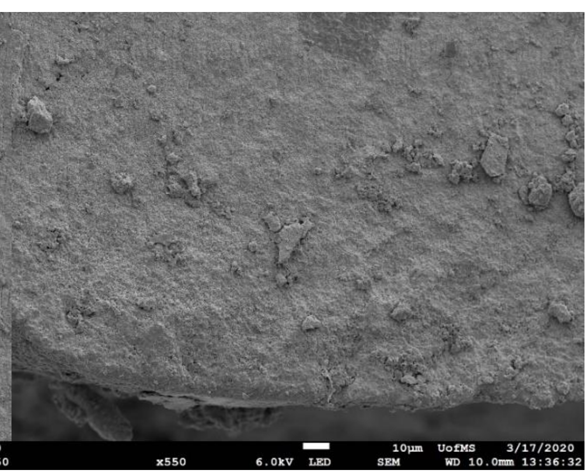

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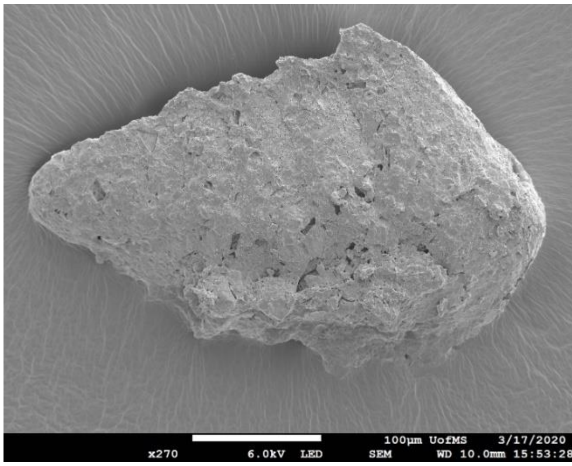
Plate 9



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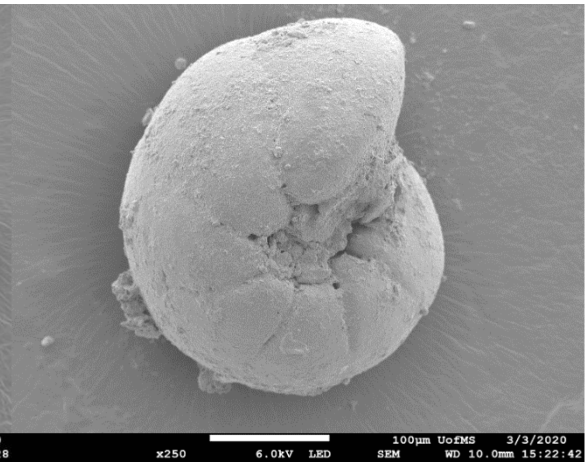

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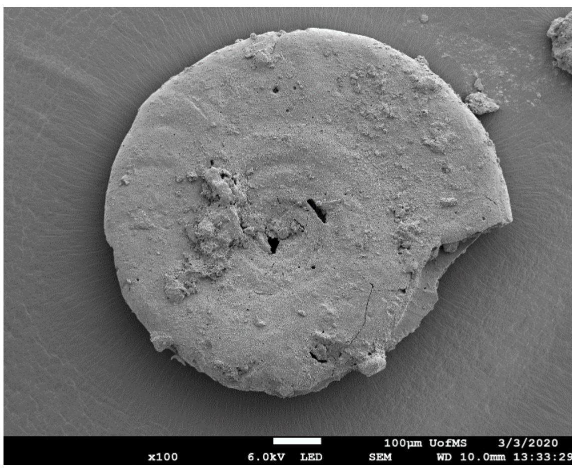

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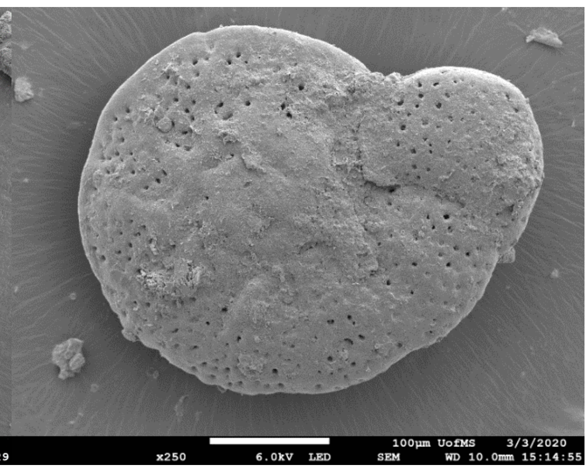

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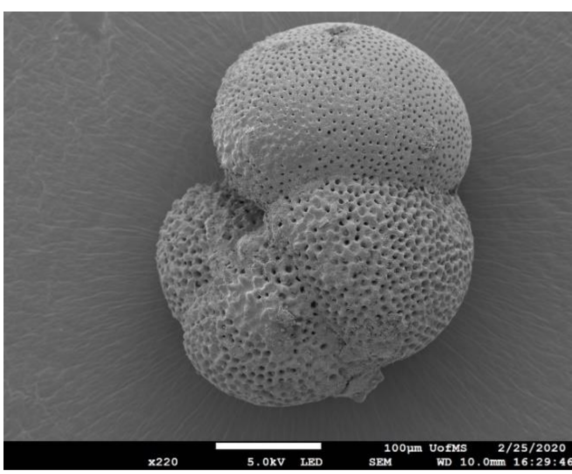

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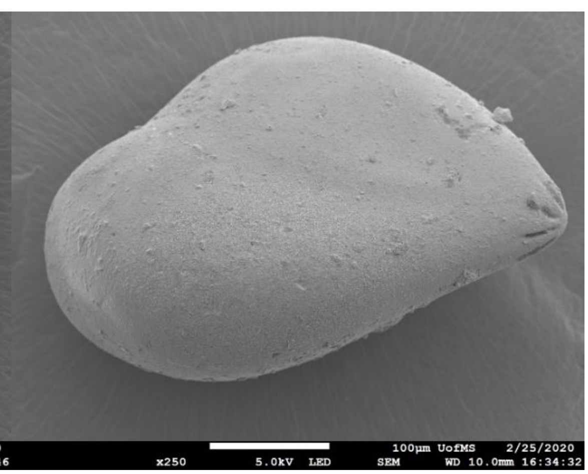


9.6

Plate 9

9.1- *Bolivina Louisiana*

9.2-*Cibicides sp.*

9.3- *Cornuspira sp.*

9.4-*Discorbis sp.*

9.5-*Globigerina sp.*

9.6- *Globulin sp.*

Plate 10

10.1-*Haphlophragmoides sp.*

10.2- *Nodosaria affinis*

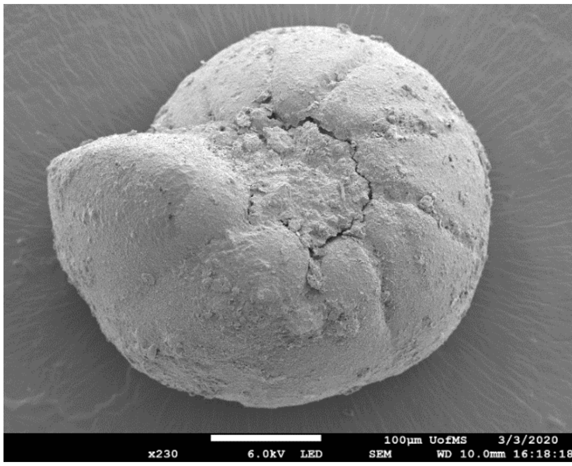
10.3- *Planulina kneffi*

10.4- *Quinqueloculina striaturata*

10.5- *Robulus sp.*

10.6- *Quinqueloculina sp.*

Plate 10



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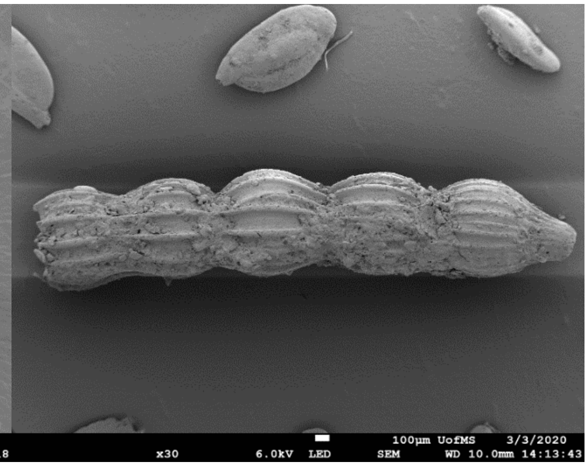

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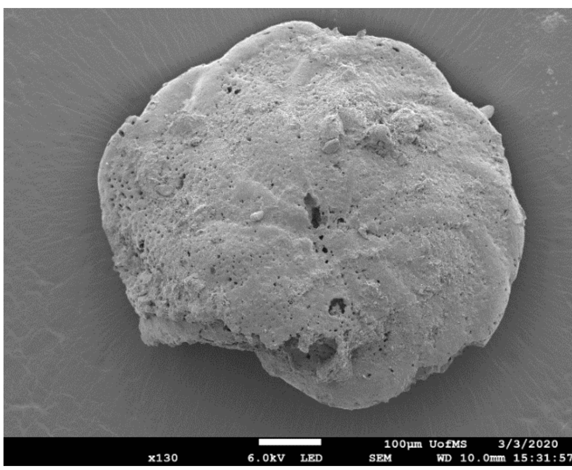

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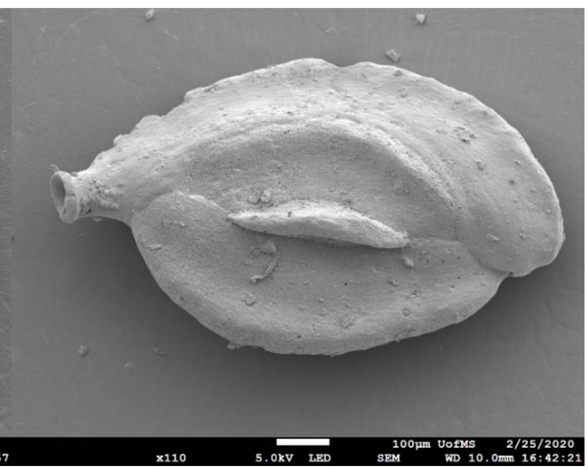

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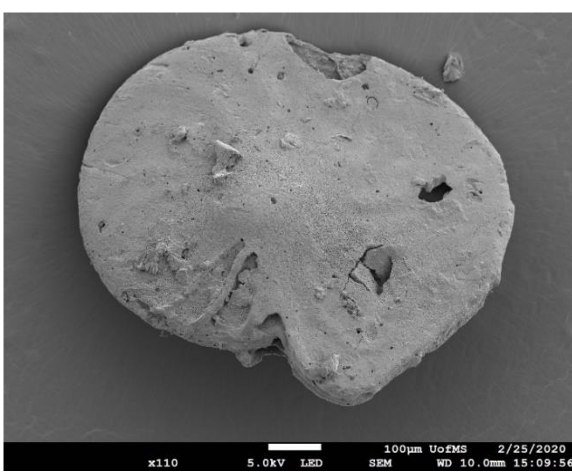

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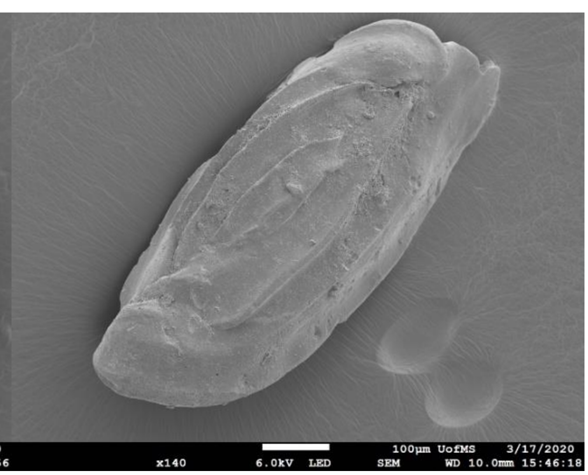

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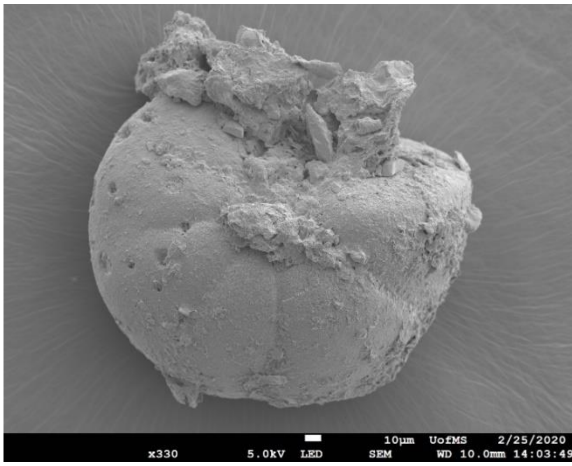
Plate 11



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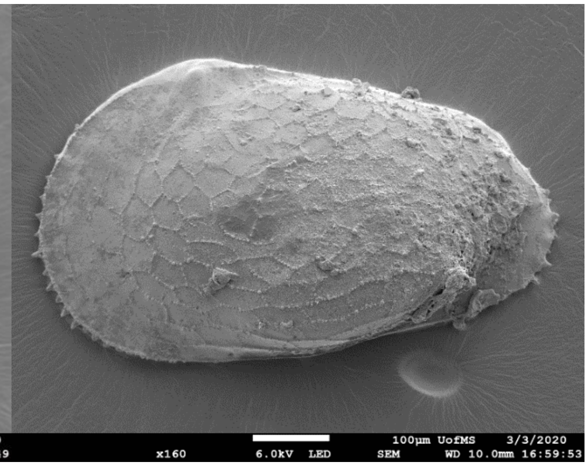

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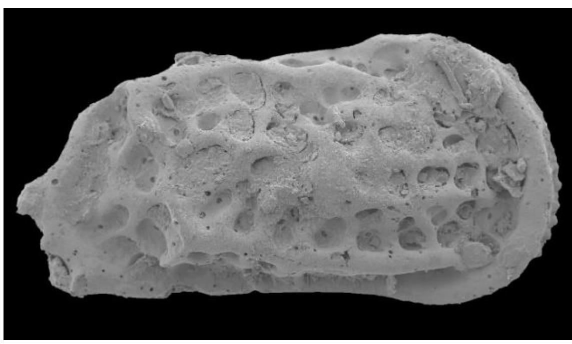

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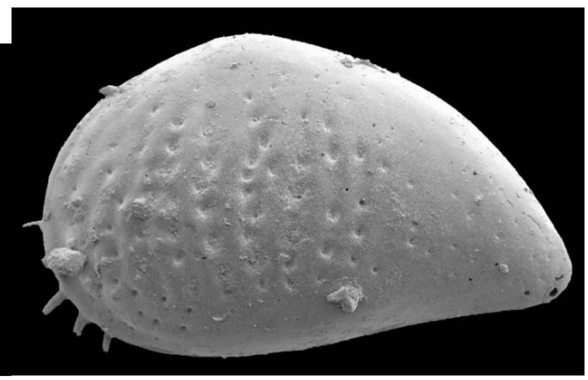

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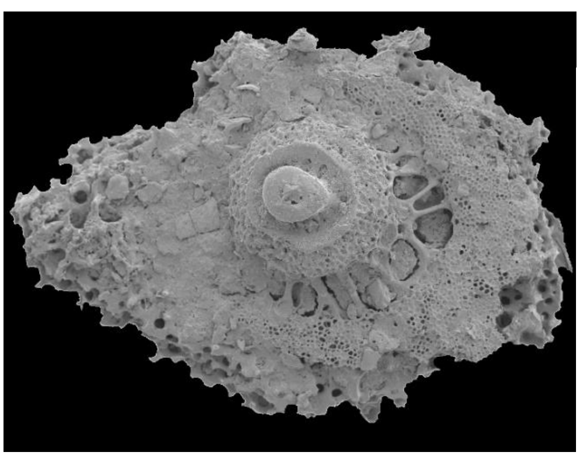


11.5

11.6

Plate 11

11.1-*Valvulineria sp.*

11.2-Unidentified Ostracod

11.3-Unidentified Ostracod

11.4-Unidentified Ostracod

11.5- Echinoid tubercle and stereom

11.6- Amall unidentified vertebra

Plate 12

12.1- *Calciosolenia fossilis, Reticulofenstra minuta*, *Pocillithus spinulifer, Reticulofenstra martinii,* and an unidentified coccolith.

12.2- *Clausicoccus fenestratus*

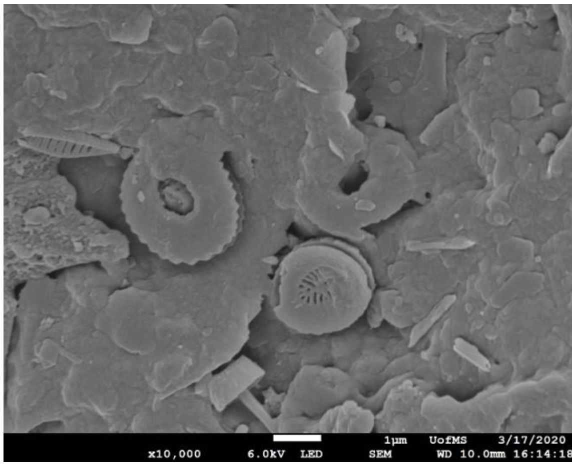
12.3-*Coccolithus formosus*

12.4-*Cruciplacolithus insteadus*

12.5-*Discoaster distinctus*

12.6-*Discoaster sublodensis*

Plate 12



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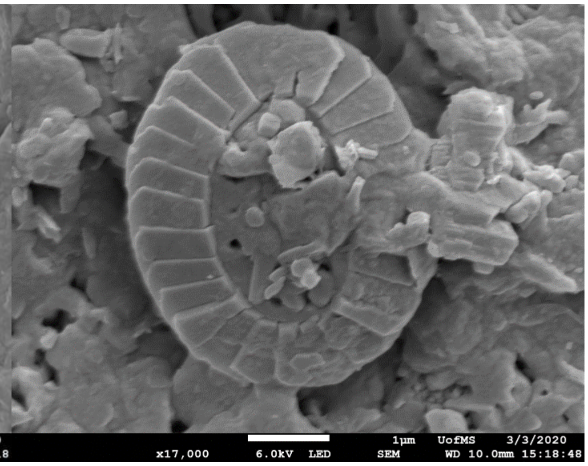

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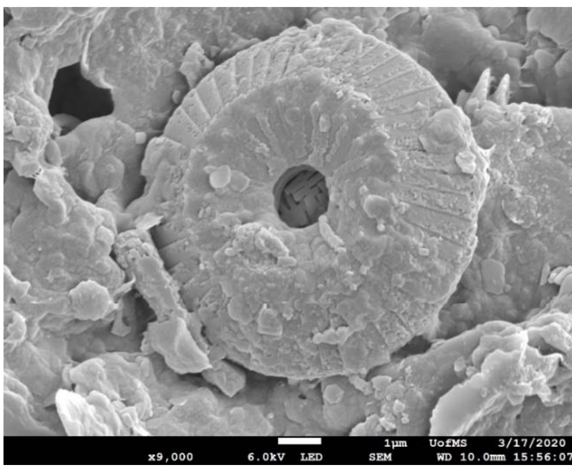

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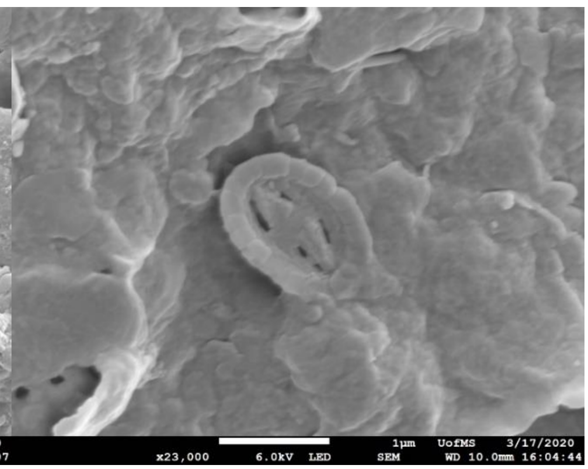
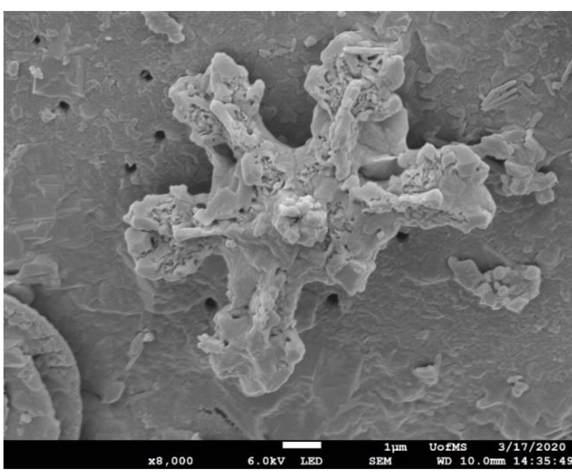


12.4



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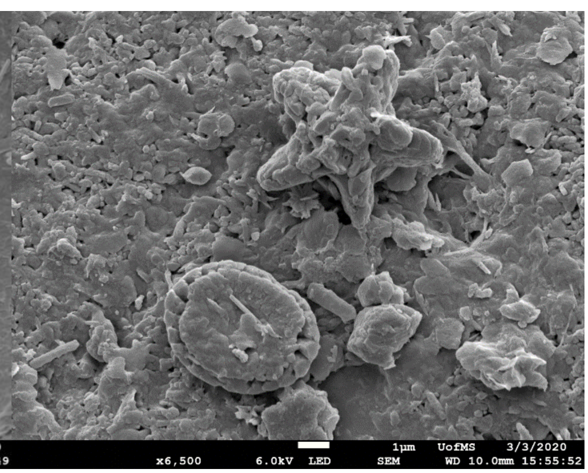
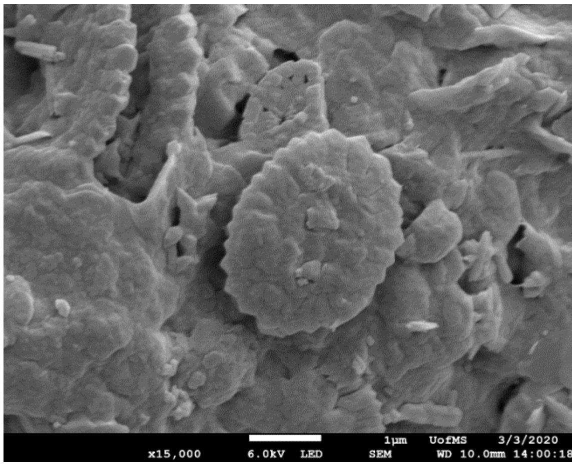
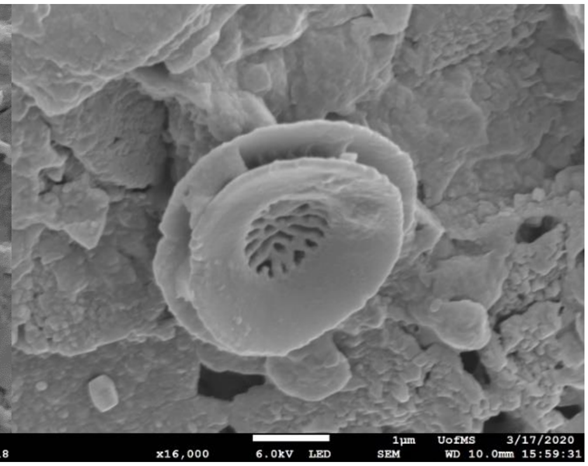


12.6

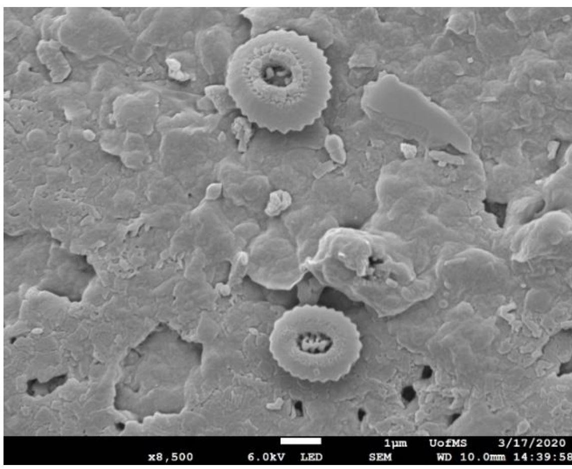
Plate 13



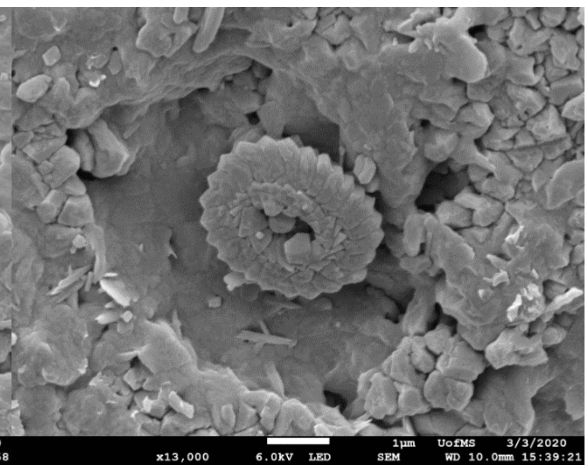
13.1



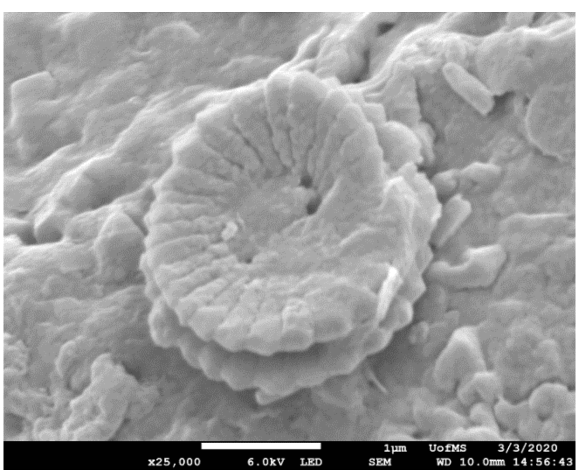
13.2



13.3



13.4



13.5

Plate 13

13.1- *Discoaster wemmelensis*

13.2- *Pontophaera*

13.3- *Reticulofentra daviesii*

13.4- *Reticulofentra hesslandii*

13.5- *Reticulofentra minuta*

APPENDIX B

SPECIMIN	SEX	WIDTH (CM.)	HEIGHT (CM.)	STERNUM WIDTH (CM)	STERNUM HEIGHT (CM)
NA1001	x	2.725	2.26		
NA1002	m	3.775	2.77		
NA1003	x	2.935	2.73		
NA1004	m	3.39	2.555		
NA1005	x	3.17	2.05		
NA1006	x		2.045		
NA1007	x	2.91	2.17		
NA1008	x	2.845	2.23		
NA1009	f		2.35		
NA1010	x	2.225	2.91		
NA1011	x	2.79	2.525		
NA1012	x				
NA1013	x	5.2	2.81		
NA1014	f	3.685	3.84	1.71	2.21
NA1015	m	3.22	3.12	0.9	1.175
NA1016	x	4.1	2.765		
NA1017	f	2.63	3.65	1.91	2.5
NA1018	x	2.695	2.22		
NA1019	x	3.485	2.9		
NA1020	f	3.525	2.99	1.1	1.93
NA1021	x	3.995	2.79		
NA1022	x	4.225	3.26	0.735	1.2
NA1023	f		3.32	1.23	1.3
NA1024	x	2.995			
NA1025	x		2.7		
NA1026	x	3.91			
NA1027	f		3.62		
NA1028	x	3			
NA1029	f	3.27	3.23	1.03	1.5
NA1030	x	4.955	2.295		
NA1031	f	4.065	3.9	1.725	2.345
NA1032	f	4.525	3.18	1.33	1.95
NA1033	f	3.7	3.58	1.37	2.05
NA1034	x	4.21	2.765		
NA1035	f	3.305	3.51	1.49	2
NA1036	x	3.965	2.615		
NA1037	x	3.41			
NA1038	f	3.31	3.2	1.155	1.835

NA1039	f	4.045	2.89	0.925	1.62
NA1040	f	3.625	2.92	1.17	1.745
NA1041	f	5.21	3.575	1.41	1.85
NA1042	m	4.56	3.01	1.045	1.59
NA1043	f	5.44	4.13	2.045	2.635
NA1044	x	2.995	3.845		
NA1045	f		4.1	1.905	2.72
NA1046	x	4.255	2.55		
NA1047	f	4.625	3.945	1.72	2.41
NA1048	x	5.045	3.335		
NA1049	f	3.05	3.83	1.53	
NA1050	f	3.86	4.075	1.975	2.26
NA1051	x	3.94	2.295		
NA1052	x	3.835	3.475	1.1	1.54
NA1053	m	3.45	3.255	1.185	1.965
NA1054	x	3.38	3.145		
NA1055	x	5.155	2.85		
NA1056	f	4	2.67	0.94	1.32
NA1057	f	4.565	4.12	1.755	2.355
NA1058	f	3.32	3.14	1.225	1.71
NA1059	x		3.695		
NA1060	m		3.355		
NA1061	m		3.05		