ABSTRACT

During the Cenozoic Era, the geologic and stratigraphic history of the State we now call Florida left invertebrate fossils that reflected the rise of a diverse marine fauna. Two geologic formations, the Tamiami and Caloosahatchee, were deposited through central and southwest Florida. Many researchers have cataloged and documented the evolution of the fauna, and describe how the regression of the Atlantic Ocean during the Cenozoic was the result of periods of glaciation and climatic warming that resulted in the changing shorelines, and the deposition of beds of invertebrate marine fossils.

This article focuses on a small sample of invertebrate fossils that reflect the form and shape of their extant fauna. Gastropoda and Mollusca marine fossils found in Tamiami and Caloosahatchee formation shell pits survived the moving shorelines of Florida during the Pliocene and Pleistocene Epochs. Surveys completed by the US Department of the Interior detected significant traces of rare earth elements, brought by ground water movement. At one fossil site in central Florida, fossils were transformed by the same ground water movement into beautiful mold aggregates of calcite crystals.

Photographic plates highlight invertebrate fossils originally collected by Mr. Al Klatt of Franklin, North Carolina. Also Mr. George Phillips of the Mississippi Museum of Natural Science in Jackson, Mississippi, provided foundational research on the Ruck's Pit, Fort Drum phosphorite mining site. Dr. Edward Petuch, of Florida Atlantic University, graciously corrected the taxonomic identification of the Gastropoda and Mollusca specimens featured in this survey.

Introduction

During the Cenozoic Era, the topograhy of Florida changed as the global climate moved from periods of glaciation to the retreat of the glaciers and the rise in the ocean levels. Cycles of glaciation on the North American continent were one factor resulting in the lowering of the ocean levels surrounding the ancient peninsula of Florida. New shorelines built up ridges of coquina and masses of shells from the diverse marine fauna. When the warming climate cycled through the periods of the Neogene, ocean water levels rose and new shoreline ridges formed. The interior terrain also changed as salt water intrusions during warming periods changed the fresh water environment for this fauna. Invertebrate animal colonies changed with the ebb and flow, and left behind a record of their fossil members.

The Tamiami and Caloosahatchee formations were deposited and reworked in the central and southwest area of the present day Florida. Spectacular fossil shell pits and other fossil sites in the commercial phosphate pits exposed Pliocene and Pleistocene formations, then attracted collectors and researchers, who have focused on the evolution of many of the invertebrate species. Phosphate mines have extracted phosphorite minerals commercially because the geologic and stratigraphic processes preserved and modified original fossil shell forms found in the Tamiami and Caloosahatchee formations.

Florida's Tamiami and Caloosahatchee Stratigraphy

After significant tectonic plate movements during the Cenozoic Era created and widened the Atlantic ocean basin, the basic continental shape of North America settled into the land mass unit we recognize today. The land mass of "Florida" and the Eastern coast of North America went through cycles of the

Atlantic sea levels rising and falling. One of the factors correlated with these sea level cycles was climate change and periods of glaciation in our Northern Hemisphere.

The flora and fauna of the Florida peninsula adapted to these cycles, and invertebrate fauna thrived in the warm tropical marine ecosystems. The basic geologic processes of erosion and deposition created many stratigraphic formations, two of which became sources of commercially mined minerals and the beautiful marine fossils. Many well-known geologists have documented the Cenozoic stratigraphic history of Florida, but when we focus on the marine fossils from Florida, two formations are often cited for their diversity of many fossil species. The Tamiami and Caloosahatchee formations contain pockets of invertebrate fossils and phosphorite deposits.

Thomas Scott et al. recognized the complexity of the depositional structure of these two formations. His work confirmed that transgressions and regressions of the warm Atlantic ocean on the Florida peninsula created shifting shorelines and the deposition of fossiliferous siliciclastic sediments and siliciclastic-bearing carbonates in the Tamiami and Caloosahatchee formations (Scott, Thomas M. ***The Geology of Florida,*** pg. 61**).**

> **“The section overlying the Hawthorn Group is a complex of often highly fossiliferous siliciclastic sediments and siliciclastic-bearing carbonates. Pliocene sediments are included in the Tamiami Formation (with its component members),…and the lower part of the carbonate and siliciclastic Caloosahatchee Formation.”**

As sea levels rose and fell through the Neogene Epoch, shoreline terraces and embayments formed environments for numerous invertebrate species. Molluscan species thrived and evolved along the changing shorelines and embayments, only to be covered by siliciclastic sediments that were redeposited and then chemically changed by groundwater movements.

The Calooshatchee and Tamiami formations shape-shifted into younger formations and blended into stratigraphic formations that stretched into the northern Atlantic coasts of the Carolinas. Similar invertebrate fossil fauna can be found in present day coastal plains of Georgia and the Carolinas (Scott, Thomas M. ***The Geology of Florida,*** pg. 65**).**

> **“The Caloosahatchee Formation of southern peninsular Florida is an often highly fossiliferous carbonate and siliciclastic unit. … As with the Tamiami Formation, the Caloosahatchee grated northward and eastward into siliciclastics. To the north, it becomes the siliciclastic Nashua Formation.”**

Researchers also stress the importance of rising and falling sea levels in creating not only lucrative ecosystems but also zones of large deposits of their fossil remains.The rising sea levels during the late Miocene, in the Pliocene Epoch, covered the “[Florida] platform” creating lagoons in Florida south of Lake Okeechobee (Scott, Thomas M. ***The Geology of Florida,*** pg. 65**).** Diverse colonies of invertebrate marine species thrived, died then repopulated shifting shorelines. As commercial phosphate mines in Florida opened and were actively mined in the nineteenth and twentieth centuries, geologists and paleontologists began to collect and research the vertebrate and invertebrate Florida fossils from the Cenozoic.

> **“During the Pliocene, much of southern Florida south of present-day Lake Okeechobee was a broad lagoon. …….. The lagoon was a warm, shallow-water protected environment where marine organisms thrived. Petuch (1992) has identified a number of endemic mollusk species from this area, several of which attained unusually large proportions due to hospitable conditions….. . “**

Deposition of Rare Earth Elements (REE) and Correlated Fossil Fauna

The basic geologic processes of erosion and deposition created many stratigraphic formations, two of which became sources of commercial mined minerals and the beautiful marine fossils. The flora and fauna of the Florida peninsula adapted to changing geologic processes affecting the entire North American continent. Uranium and phosphoritic minerals with other rare earth elements (REE) were deposited and covered along with the beds of invertebrate marine fossils. Epenshade (1956) surveyed areas of abnormal radioactivity between Ocala and Summerfield and found that uraniferous phosphorite in the areas of radioactivity, along with Miocene fossils in Miocene sediments of the Ocala limestone of Eocene age (Espenshade, Gilbert H. ***GEOLOGIC FEATURES OF AREAS OF ABNORMAL RADIOACTIVITY SOUTH OF OCALA, MARION COUNTY, FLORIDA*** **(March, 1956),** pg. 5).

> **"Interbedded clay, clayey sand, and uraniferous phosphorite occur in areas of anomalous radioactivity. Miocene fossils occur at three localities in these beds which are evidently outliers of Miocene sediments on the Ocala limestone of Eocene age."**

Other researchers as recently as 2017 have re-examined the abnormal occurrence of radioactivity and presence of REEs in the fossiliferous phosphate deposits of West – Central Florida. These surveys have focused on the minerals with the elements from the lanthanide series including yttrium, uranium and thorium (Turner, K. M. ***A Geochemical Analysis of Rare Earth Elements Associated with Significant Phosphate Deposits of West-Central Florida (2017)***.

> **"Phosphorite deposits are being investigated as a possible supply [(REEs)] such as the lanthanide series as well as yttrium, uranium, and thorium] but the overall concentrations, depositional environments, and ages are relatively unexplored."**

Turner concluded in his research that, **"**The weathering and transport of igneous and metamorphic minerals from the southern Appalachians to the Florida coast where a series of winnowing events occurred may explain the enrichment seen by our data.**"**

His research supported the supposition that phosphorite deposits in Florida's west coast were often correlated with "major icehouse conditions" and "estuarine and supratidal zones with low wave activity". He found dolomitic silts, teeth, bones, and marine fossils from a "near shore depositional environment". (Turner, K. M. ***A Geochemical Analysis of Rare Earth Elements Associated with Significant Phosphate Deposits of West-Central Florida (2017)***).

Just as in many long term geologic processes that result in significant depositions of sediment, the fossiliferous formations were affected by regional changes in sea level due to periods of glaciation and global warming, and by the erosion of metamorphic and igneous minerals from dominant land features, such as the ancient Appalachians. The eroded minerals from the continent mixed with the phosphorite componds that replaced the dead forms of the diverse marine fauna that thrived in the sea in Neogene Florida. The sediments of the Tamiami and Caloosahatchee formations were reworked and mixed with fossils and ground water with dissolved REE and radioactive minerals.

Calcification of Mollusca Fossil Fauna in Rucks Pit

One example of a geologic process that altered an existing formation can be found in the phosphorus mining operation near Lake Okeechobee. The Rucks Pit Fort Drum mining operation exposed lenses of altered Pliocene and Pleistocene Molluscan and Gastropoda fossils which were mineralized by ground water carrying REEs and calcite compounds eroded from the East Coast of the North American continent (Scott, Thomas M. ***GEOLOGICAL DISCUSSION OF THE RUCKS' PIT NORTHEASTERN OKEECHOBEE COUNTY, FLORIDA (2005),*** pg. 7)**.**

> **"The sediments exposed in the Rucks' Pit were deposited in the late Pliocene and Pleistocene under shallow water near shore conditions. Subsequent sea level fluctuations allowed for the dissolution of some shell material and the cementation of the beach and near shore shelly sands creating the rock mined from the Rucks' Pit."**

Methodology

Cleaning Process

Several dozen specimens of invertebrate Mollusca and Gastropoda species were culled from a larger collection (collected by Mr. Al Klatt of Franklin, North Carolina). The selection was based on criteria of specimen condition. Shells with little or no crushing or cracking, and some original color are more easily identified. Most shells in this sample were covered with a thin layer of matrix or sand, and were soaked in fresh water to dissolve and dislodge the clumped sand matrix. This process often revealed original markings and faint colors on several of the shells. Interestingly, interior colors in the Gastropoda's open chambers took on a fresher appearance.

The sample of Mollusca from Rucks Pit near Lake Okeechobee were originally collected by Mr. Klatt in 2004. The commercial mining and extraction process at the site included digging in a trench, from a fossil shell layer at least twelve feet below the Quaternary layer. The photographs 1a and 1b *below* captured collectors extracting fossils from the Pit walls (1a), and the excavation of the overburden by a Track hoe (1b), respectively.

Recreational collectors "working the walls" at Rucks' Pit in 2004

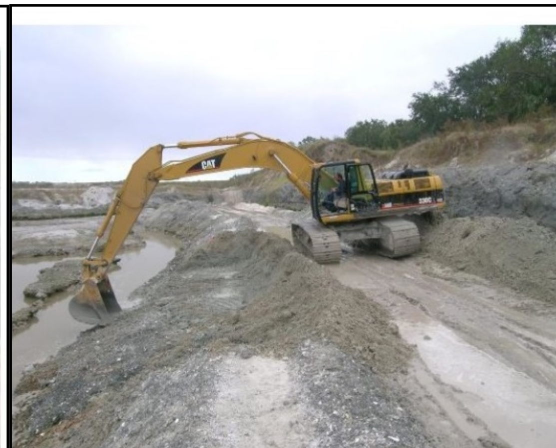

Figure 6: Track hoe removing overburden from above the basal *Mercenaria permagna* zone

Photographs 1a and 1b: Photo and Figure 6 from the SEGS Guidebook No. 45 (2005)

After specimens were extracted from the matrix, they were soaked in cold water to remove sand and marl chunks inside the complete Mollusca pieces, and on the surface of the calcite crystal clusters. Photograph 2 *below* (from the SEGS Guidebook No. 45, 2005) illustrates the mix of the fossils in the matrix in the trench wall, at the original Rucks Pit site.

Figure 7: Loose and slightly cemented *Mercenaria permagna* specimens from the first bonanza finds of 2004

Photograph 2: Figure 7 from the SEGS Guidebook No. 45 (2005)

Plate Processing

The better specimens from both samples were placed on 4” x 6” slab of polished “Imperial Black” marble. Photographs were taken with a Samsung Note 4 and cut and resized with Microsoft Photos software. This resulted in photos for the specimens that showed the most color and growth ridges.

Discussion

The fossils featured in this survey are an important record of geologic and climatic events which even now change environments of diverse fauna. Species diversity in the fauna of Florida’s Cenozoic era was affected by significant global geologic events that resulted in environmental challenges to their territorial spread and successful adaptation to these challenges. Changing shorelines, rising sea levels and beach erosion from tropical storms were and are still processes that now affect the fauna biodiversity in Florida and coastal areas of the Southeast North America.

Many invertebrate species thrived in the shallow warm waters around Pleistocene Florida, and the gastropods and mollusks that colonized the tropical seas and lagoons left behind beautiful shells recently collected from commercial mines in Florida. Some successful species from the Pleistocene have adapted to environmental changes that continue to shape our present coastlines. Many species kept their shape and form and still can be collected from the beaches of Siesta Key to the beaches of the Outer Banks of the Carolinas.

The most important story that these fossil mollusks and gastropods tell is that some species did not adapt and their unique shell fossils found in commercial phosphate mines of Florida are reminders that geologic and global climate events had measureable effects on their successful adaptation.

Mollusca and Gastropoda Fossil Plates

Figure 1 Busycotypus canaliculatus (Pleistocene)

Figure 2 Pliculofusus (Early Pleistocene)

Figure 3 Scaphella floridana (Caloosahatchee Formation)

Figure 4 Arcinella cornuta (Pleistocene)

Figure 5 Trachycardium emmonsi (Pliocene)

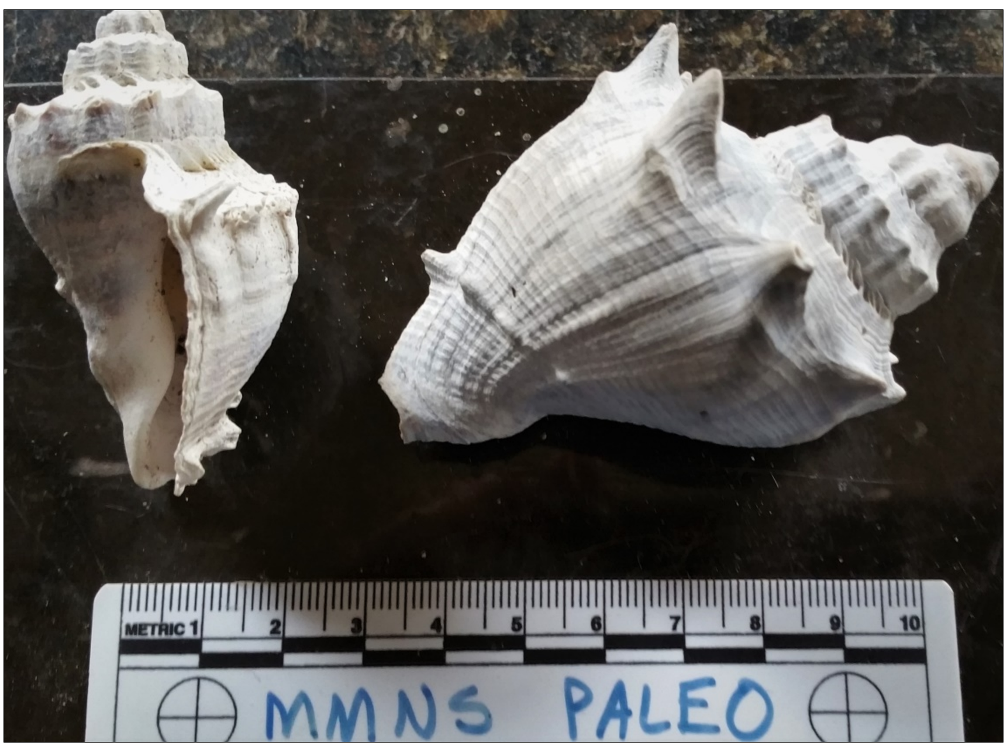

Figure 6 Melongena corona (Pliocene Caloosahatchee)

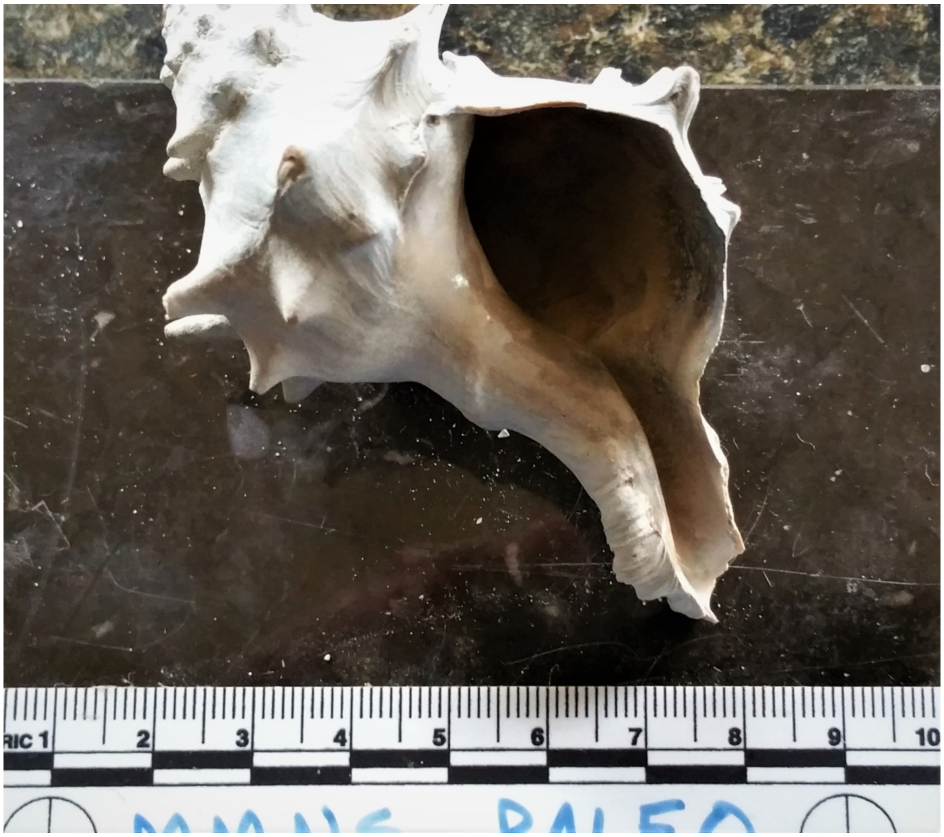

Figure 7 Echinofulgur Palm Beachensis

Figure 8 Pectinidae argopecten (Pliocene)

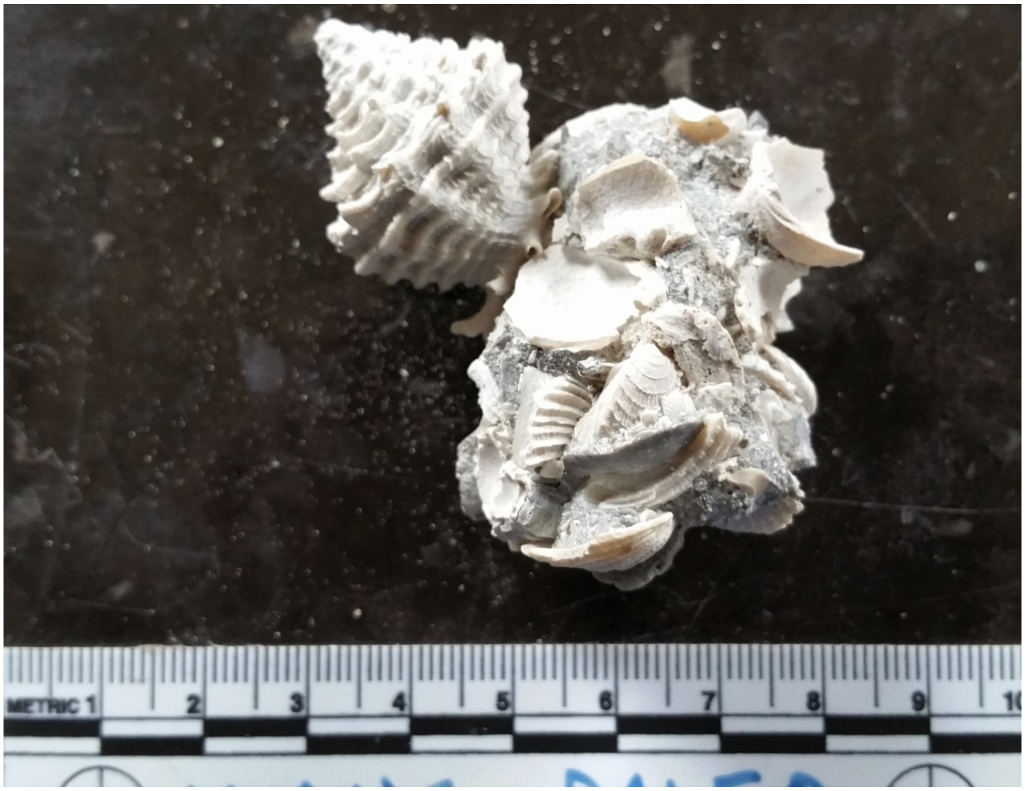

Figure 9 Vasum Embedded in Coquina Matrix (Pliocene)

Figure 10 Strombidae (Pliocene)

Figure 11 Cypraea (Pleistocene)

Rucks Pit Fort Drum Mollusca Fossil Plates

Figure 12 Lopha Actinostreon marshii (Pliocene)

Figure 13 Mercenaria permagna with calcite crystals (Pliocene)

Figure 14 Mercenaria permagna chunk with calcite crystals (Pliocene)

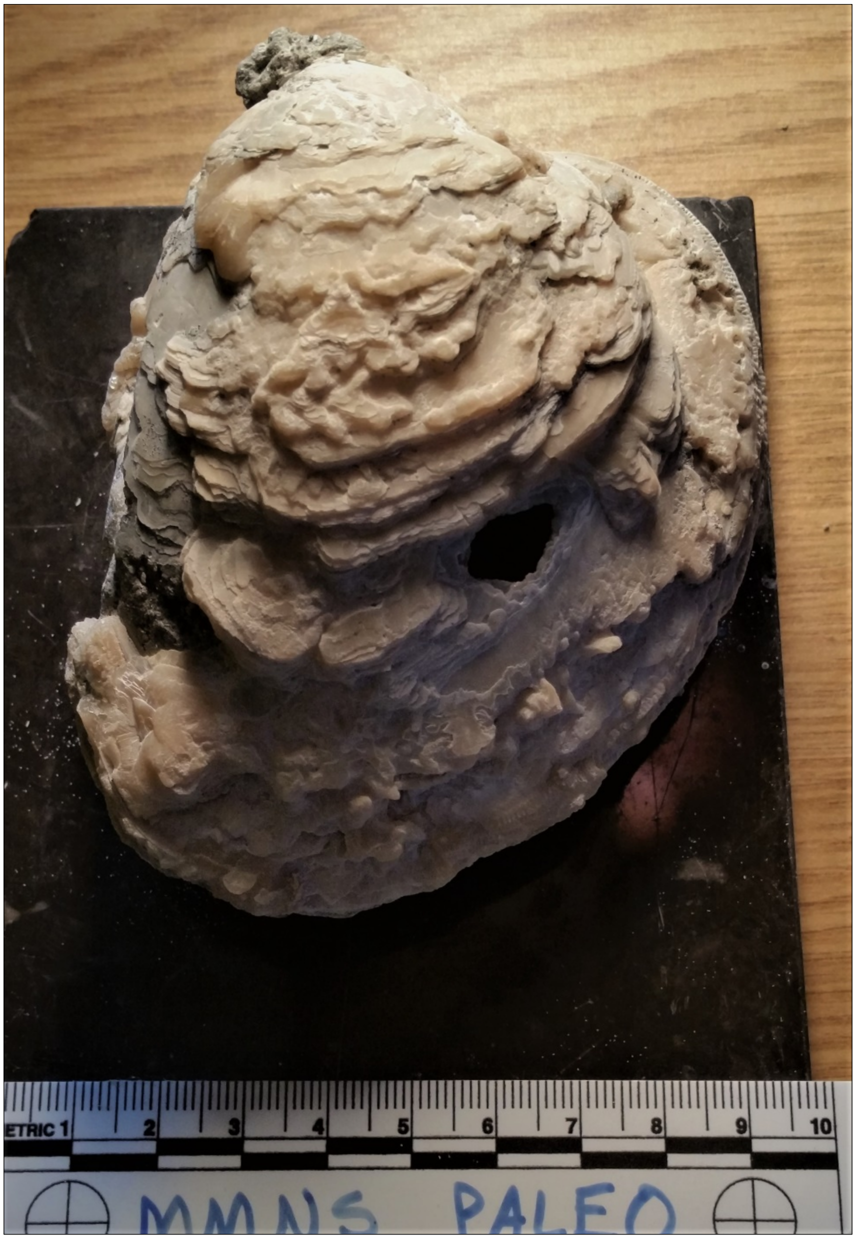

Figure 15 Mercenaria permagna (Pliocene)

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