

## The Fossil Cypraeidae of the Golden Gate Member, Tamiami Formation of Southern Florida: (Mollusca: Gastropoda: Cypraeidae)

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**ABSTRACT** The first tropical hard corals, migrating from the Caribbean, established themselves along the rim of the Everglades Pseudoatoll in the mid to late Piacenzian Pliocene, 3.1-2.6 million years ago (hereinafter “mya”). The rim or perimeter delineated the pseudoatoll, a “U shaped” feature, open in the north, which ran east southeast from the Palm Beach Reef Tract through the Miami Beach Tract, curving to the southwest before linking with the Immokalee Reef Tract on the west coast of present day southern Florida. The pseudoatoll encompassed a very large depressional lagoon. The coral and coralline facies have been designated the Golden Gate Member (Golden Gate) of the Tamiami Formation. The Lower, Middle, Upper and Uppermost beds are equivalent in time with the Pinecrest and the Fruitville Members of the Tamiami Formation, with the middle and upper layers thickest as the warming of southern Florida progressed to its maximum during Fruitville time. Nine Cypraeidae species in three genera have been recorded from the Golden Gate: one in the Lower beds, three in the Middle beds, three in the Upper beds and two in the Uppermost beds. The pseudoatoll corals, coral reefs and associated molluscan fauna became extinct as the result of a catastrophic extinction event caused by rapid and severe cooling during the Piacenzian Pliocene and Gelasian Pleistocene crossover period, circa 2.6 mya. This event also marks the end of the Tamiami Formation.

**KEYWORDS** Peninsular Florida, Everglades Pseudoatoll, Tamiami Formation, Golden Gate Member (Golden Gate), Lower Beds, Middle Beds, Upper Beds, Pinecrest Member, Fruitville Member, Cypraeidae, fossil, *Akleistostoma*, *Siphocypraea*, *Pseudadusta*, Myakka Lagoon System (Myakka), Sarasota, Polk Peninsula, Kissimmee Embayment, Kissimmee River Valley (Kissimmee), Caloosahatchee Strait, Loxahatchee Strait

### INTRODUCTION

#### Peninsular Florida - Everglades Pseudoatoll

In the late Eocene, 35.5 +/- 0.3 mya, a giant meteor impacted at what is today the mouth of the Chesapeake Bay of Maryland. The impact caused a series of giant tsunamis, estimated as high as 300+ meters, to spread out from the center of the impact. These would have swept over the entire bedrock Florida Platform which underlies peninsular Florida, that was not as yet emergent. These tsunamis would have scoured the sea bottom of unconsolidated sea floor

sediments, including the area which was to become the Everglades Pseudoatoll. The scouring is the probable cause of the Everglades Unconformity. An unconformity is a type of discontinuity whereby layers of rocks between older and younger strata are missing due to erosion or the lack of sediment deposition over an extended period of time. The unconformity dates to the end of the Ocala deposition, which is entirely missing in southern Florida and aligns with the age of the Chesapeake Bay impact.

While these tsunamis would account for the unconformity, they would not account for the lithological and geological formation of the Pseudoatoll. Unlike true atolls which are formed around sinking volcanic islands, there is no such volcanic activity in southern Florida which would account for its formation. Rather, the lithology underlying the pseudoatoll requires an alternative explanation. Unlike the older Eocene formations in central and northern Florida, which are characteristically composed of limestone with small stringers of gypsum and anhydrite (calcium sulphates) in the deep subsurface, the pseudoatoll lithofacies are replaced by fractured and vuggy (hollow cavity) dolostone (carbonate) – limestone facies which have formed fractured boulder zone areas. In addition, there is a small magnetic anomaly within a valley-like depression under the southern Everglades. This steep, high magnetic anomaly is surrounded by a low magnetic area which extends 300+ km to the south and west and 200+ km to the north and east (Klitgord *et al.*, 1984).

A possible explanation lies with the Chesapeake Bay meteor, considered a bolide meteor, *i.e.* a fireball and large impactor. The meteor entered the earth's atmosphere over the north pole and fragmented with the Chesapeake Bay impact fragment being the largest. Secondary fragments and debris spread southward, hitting all along the eastern United States and as far south as Argentina. The southern Florida platform would also have been impacted. The valley-like depression in the southern part of the present day Everglades National Park suggests a hit from a small impactor at a then depth of 250-300 m. This could account for the crater like feature and the fragmenting of the underlying limestone, to a depth of eight kilometers. Following and probably the result of the meteor impact, the Northern Hemisphere experienced a four million year ice age that dropped southern

Florida sea levels 200-300 m, resulting in land exposure over the entire Florida Platform.

In the area of the Everglades Unconformity, ground water would have penetrated the fractured limestone and dissolved its smaller fragments, leaving only limestone boulder zones in place. As a result, the surface would have collapsed over time producing a relatively shallow, irregular oval depression which extended northward and is known as the Everglades Depression. It was deepest at the possible southern impact area.

As temperatures and sea levels rose, two banks formed along the southeastern and southwestern higher edges of the depression. These were the precursor to the Everglades Pseudoatoll. As sea levels continued to rise, similar banks progressed northward along the rims of the depression, ultimately resulting in the Pseudoatoll. However, the Pseudoatoll was not a static feature. Climate and sea level changes produced the growth, erosion and even collapse of certain features. Ultimately, tropical hard coral reefs, reef tracts and coralline habitats emerged in full force, reaching their maximum development during the mid to late Piacenzian Fruitville time as the warming of southern Florida also reached its maximum, producing the richest tropical hard coral fauna ever found in the Western Atlantic. Most of the Pseudoatoll coral species also occur in the Gatunian (Caribbean) Province, adjacent to the south. This indicates that they had migrated northward from the Caribbean Region.

By Golden Gate time, mid to late Piacenzian Pliocene (c. 3.1- 2.6 mya), the pseudoatoll was open in the north. Its "U-shaped" perimeter was bounded on the east southeast, south of the Kissimmee River Valley, by the Palm Beach Reef Tract with the Miami Reef Tract representing a continuation of the former,

curving to the southwest along the southeast of the pseudoatoll. Along present day southeastern Florida, the coastal cities from Palm Beach to Miami sit atop this rim. The pseudoatoll was bounded on the west by the Immokalee Reef Tract, a broad, zonated reef system which ran south southeast from below the Myakka Lagoon System and encompassed a large chain of carbonate islands. The Long Pine Key Reefs, a set of small reefs, ran from west to east between the southernmost tips of the Immokalee and Miami Reef Tracts. The pseudoatoll was separated from the Kissimmee River Valley and Myakka Lagoon System by the Loxahatchee Strait in the east and the Caloosahatchee Strait in the west.

The lagoon within the pseudoatoll was dominated by the broad, shallow, quartz sand and carbonate Hendry Platform which fronted the leeward side of the Immokalee Reef tract to its east. The platform extended eastward to south of Lake Okeechobee. There, its termination is marked by the north-south running West Everglades Reef chain where it sloped into the deep water Loxahatchee Trough. The trough fronted the leeward side of the two eastern reef tracts and dominated that section of the lagoon.

## DISCUSSION

### Golden Gate Time

Following a drop in sea levels that presaged the mid-Piacenzian Pliocene (c. 3.1 mya), southern Florida commenced a warming trend, which progressively produced the warmest and most tropical conditions of the entire Pliocene. This was manifested in rising sea levels, the expansion of sea grass bed habitats and mangrove forests and, in the Kissimmee River Valley, the formation of the mud and clay sedimentary strata. The Golden Gate Member of

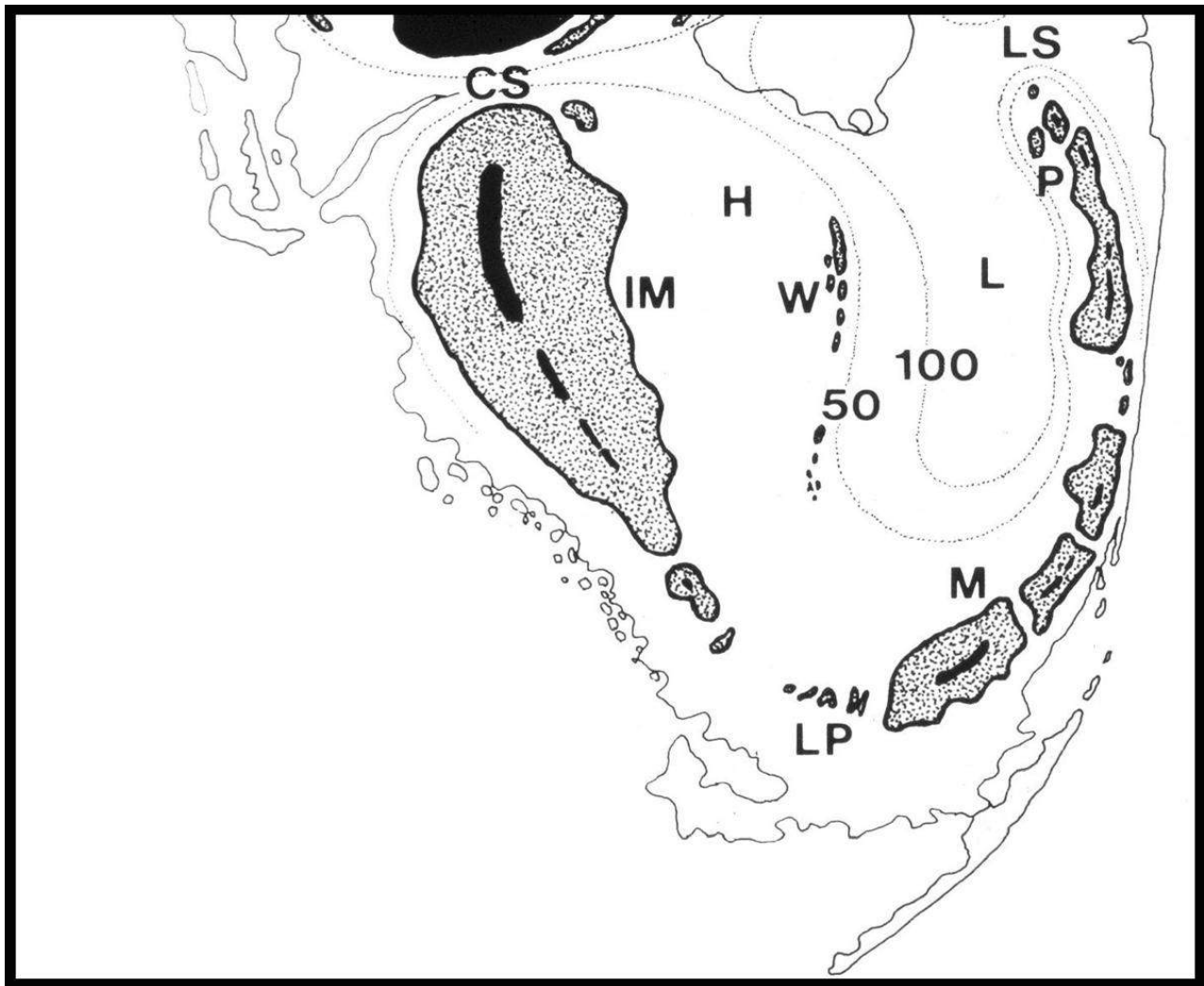
the Everglades Pseudoatoll saw the commencement of the richest tropical, hard coral fauna ever found in the Neogene western Atlantic. In addition to coral reef and coralline habitats, the pseudoatoll hosted shallow sea floors, sea grass beds and mangrove tree forests.

The Golden Gate is contemporaneous with both the uppermost Pinecrest Member and the younger Fruitville Members within the Piacenzian Pliocene Tamiami Formation of southern Florida.

### Golden Gate Member, Tamiami Formation

In 1987, Meeder, in an unpublished doctoral dissertation, mapped the wide, zonated coral reef complexes, lithology and faunal composition of Collier and Lee Counties. This was a more complete survey of the same subject published in 1980. In 1984, Swayze and Miller's survey showed that the reefs under Miami were a continuation of a reef system that extended into northern Palm Beach County. In 1985, Petuch was notified that fossil corals and mollusks were being discovered at a housing development west of Miami on Bird Road (Lakes of the Meadows). These fossils, especially corals, were very similar to those found by Meeder in Collier County. In 1986, Petuch published this data, incorporating both Meeder's and Swayze and Miller's findings. In 1992, Missimer resurrected "Golden Gate Reef" from Meeder's unpublished dissertation and gave it member status. Golden Gate refers to the Golden Gate housing development at the old Mule Pen Quarry, Naples, Florida. The name has been shortened to Golden Gate Member and encompasses the coral reefs, reef tracts and coralline limestones that surround the Everglades basin.

The areal distribution of the Golden Gate Member follows the shape of the reef tracts of



**Figure 1. Map reflecting the Everglades Pseudoatoll.** CS = Caloosahatchee Strait; LS = Loxahatchee Strait, H = Hendry Platform, IM = Immokalee Reef Tract, W = West Everglades Reef Tract, L = Loxahatchee Sound, M = Miami Reef Tract, LP = Long Pine Reefs. Contours in meters below mean Pliocene sea level. Adapted from Petuch *et al.* 2018, figure 1.5 at p. 37.

The Everglades Pseudoatoll. In the west, member thickness varies from 15 m to 5 m in Collier County. The member is 5 m below the surface at the old Mule Pen Quarry. In the east, the thickness is over 50 m under the Atlantic Coastal Ridge. The facies consist of interspersed (interbedded) highly fossiliferous limestones, including mostly unconsolidated layers of carbonate grains (dolomite silts) and cemented corals (caliculitites), highly porous, vuggy limestone molds, and limestone containing densely packed fossil corals and

mollusks intermixed. Small amounts of quartz sand are present in some of the facies.

Of note, sand flats covered with sea grass, as well as mangrove forests, also interfingered with the reefs and reef tracts in the pseudoatoll providing substantially the same habitats as the Myakka Lagoon System and the Kissimmee River Valley to the north.

### Golden Gate Member (Lower, Middle, Upper and Uppermost Beds)

The Golden Gate contains four depositional beds. They correspond in time to the uppermost Pinecrest Member (Lower), and Fruitville Members Unit 4 (Middle), Fruitville Unit 3 (Upper) and Fruitville Unit 2 (Uppermost), *in seriatim* oldest to youngest. These are time equivalents, not member equivalents. The Golden Gate is a separate Member. Fossil Cypraeidae collected in the pseudoatoll from other than coralline habitats belong to either the Pinecrest or Fruitville Members.

The Golden Gate beds form a continuum from Lower through Uppermost beds without any defining breaks or separation between them. Assignment of individual bed levels has been done through Index fossils. Index fossils are fossils which have a short vertical range indicating a narrow range in time, wide geographic distribution and exhibit rapid evolutionary trends. They are used to define, identify and correlate geologic and/or faunal strata. The Piacenzian molluscan fossils of southern Florida meet the criteria and represent ideal Index fossils with the Cypraeidae, *Hystrivasum*, *Strombus* and *Chicoreus* being particularly useful.

Portions of the Lower (basal) Beds of the Golden Gate were exposed at both the Bird Rock development west of Miami and in Collier County on the west coast. These showed that the tropical, hard coral reefal deposition began in the early middle Piacenzian time, c. 3.1 mya, and was contemporaneous with the uppermost Pinecrest Member. The Bird Rock site contained many classic Pinecrest fossils, e.g. *Hystrivasum olssoni* (Hollister, 1971) from Kissimmee Pinecrest facies, but only one Cypraeidae species. *Akleistostoma (Mansfieldicypraea) miamiensis* Petuch and

Drolshagen, 2011 was the first Cypraeidae species associated with coralline environments in the Golden Gate.

The Golden Gate reached its maximum development in the mid to late Piacenzian, *i.e.* Fruitville Time. While there is no clear delineation of the beds above the base, the recording of *Siphocypraea (Seminolecypraea) grovesi* Petuch, 1998 in both Fruitville Member Unit 4 at the Quality Aggregates Pit in Sarasota and the old Mule Pen Quarry, Naples, Florida, allows a Middle Beds assignment of the fossil Cypraeidae recorded within similar strata. Other Index Fossils recorded in Unit 4 at Sarasota and the Golden Gate include *Strombus sarasotaensis* Petuch, 1994 and *Hystrivasum lindae* Petuch, 1994.

The recording of *Pseudadusta ketteri* (Petuch, 1994) in both Fruitville Member 3 at the APAC Pit in Sarasota and in the quarries at both Bonita Springs and Naples allows an Upper Beds assignment of the fossil Cypraeidae recorded within similar strata in the Golden Gate. Other Index Fossils recorded in Unit 3 at Sarasota and the Golden Gate include *Chicoreus miccosukee* Petuch, 1991 and *Pterorhytis squamulosa* Petuch, 1994.

No Golden Gate restricted fossil Cypraeidae from the Uppermost beds have been recorded in equivalent units. However, other Index fossils, such as *Hystrivasum hertweckorum* Petuch, 1994 and *Chicoreus judeae* Petuch, 1994, have been recorded from Unit 2 at Sarasota and in the Golden Gate. This allows an Uppermost beds assignment to the Cypraeidae recorded within similar strata.

### Extinction event

The intervals between successive Fruitville Member units represent periodic molluscan

impoverishment events which are also reflected in the Kissimmee River Valley Equivalent Units and the Golden Gate beds. These events were relatively short lived and temporary in nature, although specific species, including Cypraeidae, disappeared from the collecting sites available to modern day collectors. Their continued isolated presence is inferred by renewed speciation and radiation once climatic conditions once again became supportive. However, in the late-Piacenzian, following Unit 2 and Golden Gate equivalent time (Uppermost beds), during the Piacenzian, Pliocene and Gelasian Pleistocene crossover period, c. 2.6 mya, there occurred the first of a two stage catastrophic extinction event that permanently altered both the geology and the habitats of molluscan populations.

As a result of a period of cooling prior to Unit 2 time, sea levels had already dropped resulting in more diverse and isolated habitats. The brief warming that followed brought little respite to the reduced molluscan populations, severely limiting renewed speciation and radiation. This wounding event was closely followed by a major extinction event, the first stage of the two

stage event, caused by rapid and severe cooling that resulted in the catastrophic extinction of the pseudoatoll corals, coral reefs and the associated molluscan (Cypraeidae) populations. The Myakka and Kissimmee sea grass beds, mud flats and mangrove forests also fell victim to this catastrophic event with the *Akleistostoma*, *Calusacypraea* and *Pseudadusta* genera becoming extinct. Lastly, this event marks the end point of the Tamiami Formation.

### Golden Gate Member Cypraeidae

Golden Gate Cypraeidae species inhabited coral reef lagoon back reef areas consisting of dense beds of solitary cup (*Antillia* Duncan, 1864, now *Trachyphillia* Milne Edwards & Haime, 1849) and rose (*Manicina* Ehrenberg, 1834) corals which were embedded in carbonate sand and mud. These interfingered with small open sand patches covered in sea grass. Together, they appear to have formed the habitats for the species listed below as some specimens collected are encased to some extent in coral while others are not. Altogether, nine species in three genera have been collected in Golden Gate deposits.

#### Uppermost coral beds (Fruitville Unit 2 equivalent Time)

*Siphocypraea (Lokossea) mulepenensis* Petuch, 1991 (Figure 2A)

*Pseudadusta roachi* Petuch and Drolshagen, 2011 (Figure 2B)

#### Upper coral beds (Fruitville Unit 3 equivalent Time)

*Pseudadusta collierensis* Petuch and Drolshagen, 2011 (Figure 2C)

*Pseudadusta fehsei* Petuch and Drolshagen, 2011 (Figure 2D)

*Pseudadusta ketteri* (Petuch, 1994) (Figure 2E)

#### Middle coral beds (Fruitville Unit 4 equivalent Time)

*Siphocypraea (Seminolecypraea) grovesi* Petuch, 1998 (Figure 2F)

*Pseudadusta (Bithloa) irisae* Petuch and Drolshagen, 2011 (Figure 2G)

*Pseudadusta lindae* (Petuch, 1986) (Figure 2H)

#### Lower coral beds (Uppermost Pinecrest equivalent Time)

*Akleistostoma (Mansfieldicypraea) miamiensis* Petuch and Drolshagen, 2011 (Figure 2I)

Table 1. Golden Gate Member depositional beds and their respective Cypraeidae species.

## Origins

Five of the six species of the subgenus *Akleistostoma* (*Mansfieldicypraea*) Petuch and Drolshagen, 2011 have been recorded exclusively from the west coast Sarasota quarries. Only *A. (M.) miamiensis* has been recorded from the east coast lower beds at the Bird Rock development west of Miami. It can be considered a relictual species. The species possess larger and more developed aperture dentition and better developed auricles. From the dorsal aspect, all six species bear a resemblance to *Akleistostoma carolinensis* (Conrad, 1841) and are probably evolutionary offshoots of that widespread species.

Recorded from both the Sarasota quarries and the coralline middle beds old Mule Pen Quarry in Naples, *S. (S.) grovesi* is most similar to the older *Siphocypraea (Seminolecypraea) trippeana* Parodiz, 1988, its probable ancestor. *Pseudadusta lindae* has been recorded from both the Bird Rock development and more commonly from the west coast coralline quarries at Bonita Springs and Naples. Its ancestor is unknown. The elongated *P. (B.) irisae* has only been recorded from the west coast coralline quarries, its ancestor is also unknown.

Recorded from both the Sarasota quarries and the coralline upper beds at west coast quarries, *P. ketteri* resembles an elongated *P. lindae*, its probable ancestor. Both *P. collierensis* and *P. fehsei* have only been recorded from the west coast coralline quarries. The former resembles a smaller and more rotund *P. lindae*, its probable ancestor, while the latter resembles a larger, more inflated *P. (B.) irisae*. However, its ancestor is unknown.

Recorded from the uppermost beds of the west coast quarries, *P. roachi* also resembles *P.*

*lindae* which probably served as an ancestor to a number of species (see above). The large and globular *S. (L.) mulepenensis* resembles a much more globular *Siphocypraea cannoni* Petuch, 1994, a possible ancestor.

Note: Due to the very limited number of quarries and collecting sites located on the east coast reef tracts as well as the depth of the Golden Gate in those areas, the molluscan fauna, including the Cypraeidae, have been poorly sampled. While the west coast quarries have offered better access in past, the quarries (mostly closed at present) were still limited in number. More extensive access to the Golden Gate would probably show more extensive species distribution than is presently known.

For detailed genera and species descriptions, background information and discussion, see *Jewels of the Everglades, The Fossil Cowries of Southern Florida, 2018*, by Edward J. Petuch, David P. Berschauer, and Robert F. Myers.

## ACKNOWLEDGEMENTS

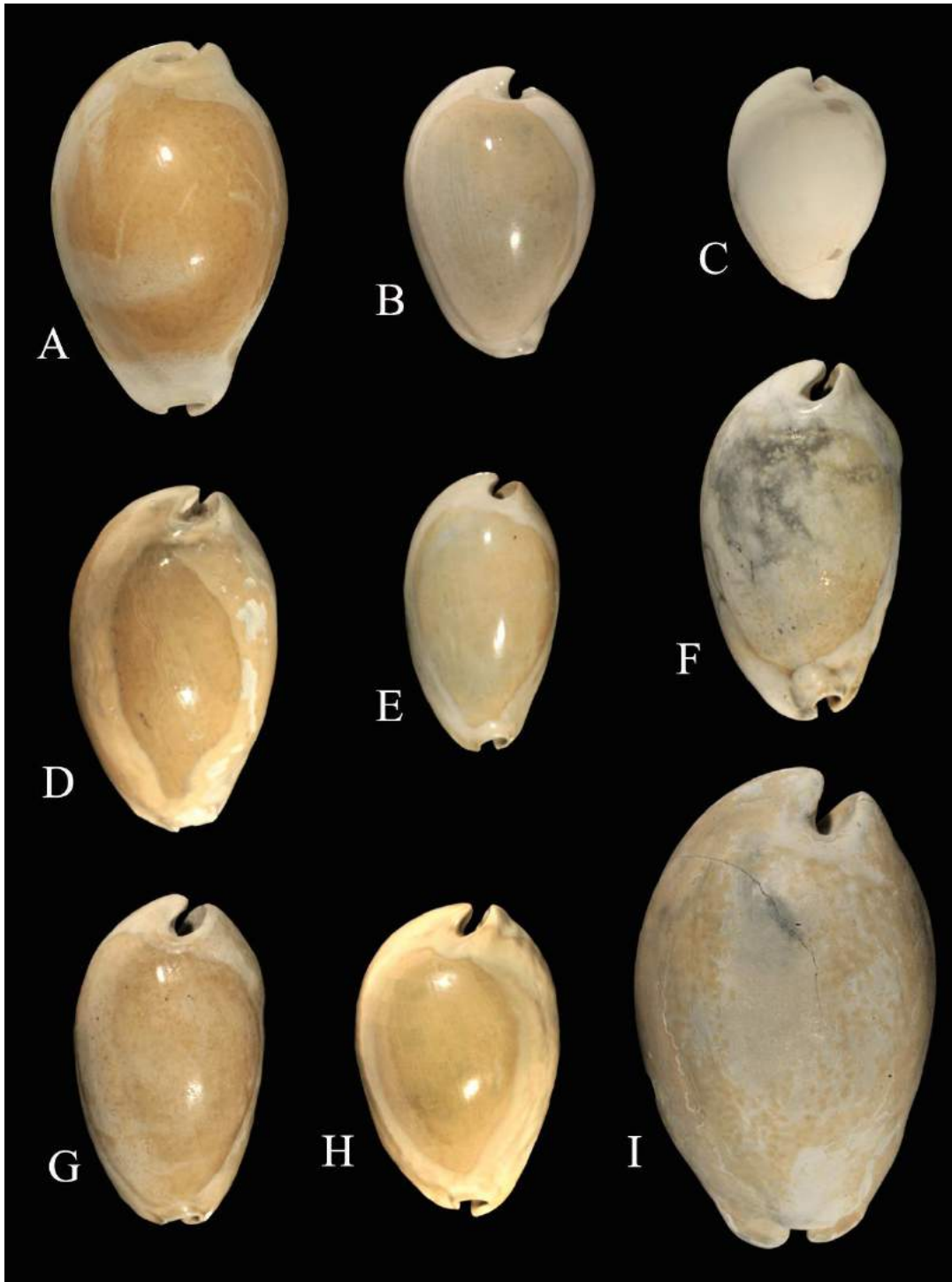
This article is based largely on the related collective works of Dr. Edward J. Petuch which encapsulate his 45 years of field and academic work with the geology, paleogeography and fossil fauna of Florida.

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**Figure 2. Golden Gate Member Cypraeidae.** A = *Siphocypraea (Lokosseae) mulepenensis* Petuch, 1991, 66.7 mm; B = *Pseudadusta roachi* Petuch and Drolshagen, 2011, 52.2 mm; C = *Pseudadusta collierensis* Petuch and Drolshagen, 2011, 42.2 mm; D = *Pseudadusta fehsei* Petuch and Drolshagen, 2011, 63.2 mm; E = *Pseudadusta ketteri* (Petuch, 1994), 50.1 mm; F = *Siphocypraea (Seminolecypraea) grovesi* Petuch, 1998, 64.7 mm; G = *Pseudadusta (Bithloa) irisae* Petuch and Drolshagen, 2011, 60.0 mm; H = *Pseudadusta lindae* (Petuch, 1986), 56.0 mm; I = *Akleistostoma (Mansfieldicypraea) miamiensis* Petuch and Drolshagen, 2011, 87.1 mm.