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**The Fossil Cypraeidae of the Fruitville Member (Unit 3) and Kissimmee River Valley Equivalent, Tamiami Formation of Southern Florida:  
(Mollusca: Gastropoda: Cypraeidae)**

John D. “Duffy” Daughenbaugh  
203 North Wilton Place, Los Angeles, CA. 90004  
[shoduffy@ca.rr.com](mailto:shoduffy@ca.rr.com)

**ABSTRACT** Four species of the *Pahayokea* (*Gardnericypraea*) Petuch and Drolshagen, 2011 subgenus are reclassified as *Akleistostoma* (*Gardnericypraea*) subgenus species. This represents a continuation of geographically separate, but parallel, evolutionary tracks throughout the Piacenzian Pliocene Tamiami Formation.

**KEYWORDS** Tamiami Formation, Fruitville Member (Unit 4), Black Layer, Unit 4 equivalent, Fruitville Member (Unit 3), Unit 3 equivalent, Unit 2 equivalent, Golden Gate Member, Cypraeidae, fossil, *Akleistostoma*, *Siphocypraea*, *Pahayokea*, *Calusacypraea*, *Okeechobea*, *Pseudadusta*, Myakka Lagoon System (Myakka), Sarasota area, Kissimmee Embayment, Kissimmee River Valley (Kissimmee), Polk Peninsula, Caloosahatchee Strait, Loxahatchee Strait

## INTRODUCTION

The transition from the highest sea levels of Unit 4 time to Unit 3 time at Myakka and Kissimmee was marked by falling sea levels as tropical conditions eased. This resulted in reduced and altered molluscan habitats and in the adaptive speciation of the Cypraeidae populations. The ten Fruitville Member (Unit 4) Cypraeidae species in five genera of the Myakka Lagoon System were followed by ten new species in four genera which evolved in Fruitville (Unit 3) time. In the Kissimmee River Valley, the nine Unit 4 equivalent species in three genera were reduced to four new species in two genera which emerged in that area. While *Okeechobea* (Petuch, 2004) Unit 3 equivalent species have not been recorded from Kissimmee, their presence may be inferred as species have been recorded from Unit 2 equivalent strata.

## Unit 3 Transition

The transition from the highest sea levels of the Tamiami subsea, which was the hallmark of Unit 4 time, to Unit 3 time at Myakka and Kissimmee was marked by falling sea levels, resulting in reduced and altered molluscan habitats. Tropical conditions still persisted, but were less intense. At this time, all Unit 4 Cypraeidae species were replaced by new species in a sequential evolution as the populations adapted to the altered habitats during the subsequent Unit 3 time.

Unit 3, along with Unit 4, also marked the highpoint of Cypraeidae diversity in the late Piacenzian Pliocene. The decline in diversity would not be precipitous, and included a significant interim reprieve during Unit 2 time. For the Cypraeidae genera this meant either adaptation or extinction.

### Fruitville (Unit 3) Myakka Lagoon System

In the western Myakka estuary and lagoon system, Fruitville Unit 3, present day Sarasota region, the receding sea levels reduced, but did not eliminate the mangrove forests, leaving significant remnants in the most seaward sections. However, the “Black Layer” which characterized Unit 4 was not dominant in Unit 3. The last of the *Akleistostoma (Paludacypraea)* Petuch and Drolshagen, 2011 species, *i.e. A. (P.) walleri* Petuch, Berschauer & Myers, 2018, was confined to this layer. Specimens exhibit the black/blue or tan staining associated with brackish, swamp like muddy estuaries. Other species inhabited the interspersed estuarine mud flats which also served as a shared habitat with the remnant Black Layer and intertidal shoals.

The adjacent seaward waters consisted of large quartz sand intertidal shoals which dominated the Cypraeidae habitats. These shoals hosted extensive beds of the pearly mussel *Perna conradiana* (d’Orbigny, 1852) which formed low, unlayered, massive reef like mounds, half buried in the substrate. Patches of sea grass were scattered between the mussel beds and hosted many of the Unit 3 Cypraeidae. These patches were associated with *Calusacypraea sarasotaensis* (Petuch, 1994) and *Calusacypraea (Myakkacpraea) kelleyi* (Petuch, 1998). They also hosted *Akleistostoma rilkoii* (Petuch, 1998), *Siphocypraea parodizi* (Petuch, 1994), *Pseudadusta kalafuti* (Petuch, 1994) and *Pseudadusta ketteri* (Petuch, 1994). These Unit 3 patches also hosted the first true *Siphocypraea* (Heilprin, 1886) species, *i.e. S. cannoni* Petuch, 1994.

Myakka Cypraeidae populations remained largely isolated in Unit 3 time. However, *P. ketteri* has been recorded in both Myakka and the Golden Gate of the Everglades Pseudoatoll in Lee and Collier Counties. However, the

neotenic Cypraeid genus *Calusacypraea* (Petuch, 1996) remained isolated in Myakka throughout Pinecrest and Fruitville times.

### Fruitville (Unit 3) Kissimmee River Valley Equivalent

In the east, despite the presence of extensive mangrove forests and mud flats within Kissimmee, the mangrove forests do not appear to have served as a principle Cypraeidae habitat during either Unit 4 or 3 equivalent time. While mud flats did serve as a habitat during Unit 4 equivalent time, by Unit 3 equivalent time, the remaining known Cypraeidae populations in the Rucks Pit and its southern extension habitats were living on sea grass beds and sand patches in the embayment. While no Index Fossils are available, the species were recorded from above Unit 4 equivalent facies. The sand patch facies at Rucks Pit were unchanged throughout both units. NOTE: Some Cypraeidae Unit 3 equivalent species and cf. species in the Dickerson Aggregates Pit habitats, approximately 2 km east of Rucks Pit, exhibit the black/blue and tan staining typical of mangrove habitats. As these were collected from spoil piles, a specific unit could not be assigned.

The receding sea levels had a dramatic effect upon the Cypraeidae populations in the Kissimmee Embayment and its southern sedimentary deposits. Only four species have been recorded from Unit 3 equivalent facies vs. eight from Unit 4 equivalent time. It is, however, noteworthy that while no *Okeechobea* Petuch, 2004 species have been recorded, their existence may be inferred as several species of the genus emerged during Unit 2 equivalent time.

### Unit 3 Ends

The end of Unit 3 time at Myakka was marked by the commencement of a second pulse of falling sea levels, albeit modest compared to the drop experienced from Unit 4 to Unit 3 time. This was caused by cooling temperatures. Sea

levels also dropped in Kissimmee. This resulted in altered habitats as reflected in Unit 2 and Unit 2 equivalent facies and species. This was an interim reprieve for the Cypraeidae populations and resulted in the last radiation and Cypraeidae speciation within the Piacenzian Pliocene Tamiami Formations.

### Fruitville Member Species – Unit 3 \*G = Also in the Golden Gate Member

Myakka Lagoon System (Sarasota)

*Akleistostoma rilkoii* (Petuch, 1998)

*Akleistostoma (Mansfieldicypraea) juliagardnerae* Petuch and Drolshagen, 2011

*Akleistostoma (Gardnericypraea) buchecki* (Petuch and Drolshagen, 2011)<sup>++</sup>

*Akleistostoma (Paludacypraea) walleri* Petuch, Berschauer & Myers, 2018

*Siphocypraea cannoni* Petuch, 1994

*Siphocypraea (Seminolecypraea) parodizi* Petuch, 1994

*Calusacypraea sarasotaensis* (Petuch, 1994)

*Calusacypraea (Myakkacypraea) kelleyi* (Petuch, 1998)

*Pseudadusta ketteri* (Petuch, 1994) \*G

*Pseudadusta (Bithloa) kalafuti* (Petuch, 1994)

Kissimmee Embayment (Kissimmee Valley restricted) Unit 3 equivalent

*Akleistostoma (Olssonicypraea) diegelae* (Petuch, 1994)

*Pahayokeya penningtonorum* (Petuch, 1994)

*Pahayokeya heimeri* Petuch and Drolshagen, 2011

*Pahayokeya (Kissimmecypraea) leonardi* Petuch and Drolshagen, 2011

**Table 1. Fruitville Member Species - Unit 3.**

Altogether, 13 species in five genera have been collected in Fruitville Unit 3 deposits and its equivalent.

### RECLASSIFICATION<sup>++</sup>

In 1998, Petuch described three new species in Units 10, 7 and 4 from the Myakka Lagoon System (Sarasota area) which he classified in the subgenus *Siphocypraea* (*Akleistostoma*) Gardner, 1948 as follows:

Unit 10      *S. (A.) erici* (Petuch, 1998)

Unit 7        *S. (A.) mansfieldi* (Petuch, 1998)

Unit 4        *S. (A.) jenniferae* (Petuch, 1998)

In 2004, Petuch recognized *Akleistostoma* (Gardner, 1948) as a full genus, thereby reclassifying the three species above as *Akleistostoma* species. *Akleistostoma carolinensis* (Conrad, 1841) is the type species of the genus.

In 2004, the *Pahayokeya* (Petuch, 2004) genus was also introduced as a subgenus of *Siphocypraea* Heilprin, 1886, representing an offshoot of the *Siphocypraea (Seminolecypraea) trippeana* Parodiz, 1998 lineage. *Pahayokeya* species were described as broader, fatter shells

with well developed and often flaring margins as compared to *Siphocypraea* subspecies. The resemblance to *Akleistostoma* genus species in shell shape and general appearance was noted. However, the *Siphocypraea* features of a narrow aperture and a coiled apical sulcus, some more coiled than others, were determinative. *Pahayokeya penningtonorum* Petuch, 1994 was designated as the type species. All species within the genus were restricted to the Kissimmee Embayment and River Valley.

In 2011, Petuch and Drolshagen recognized *Pahayokeya* as a full genus and proposed the subgenus *Gardnericypraea* Petuch and Drolshagen, 2011 within the *Pahayokeya* genus, placing all three *Akleistostoma* 2004 species and a newly described Unit 3 species within that subgenus. *Pahayokeya (Gardnericypraea) mansfieldi* was designated the type species of the subgenus. At that time, the four species of the subgenus were classified as follows:

Unit 10	<i>P. (G.) erici</i> (Petuch, 1998)
Unit 7	<i>P. (G.) mansfieldi</i> (Petuch, 1998)
Unit 4	<i>P. (G.) jenniferae</i> (Petuch, 1998)
Unit 3	<i>P. (G.) buchecki</i> Petuch and Drolshagen, 2011

The subgenus represented large, highly inflated cowries that lack recurved apical sulci (*i.e.* a coiled apical sulcus) and have wide, flaring apertures. This does not accord with *Pahayokeya* genus described features, *i.e.* coiled apical sulci and narrow apertures. In comparison, all *Akleistostoma* species show a wide range of features, but all also share an essentially straight or slightly recurved apical sulci and wide, open and widening apertures. The contradictions with true *Pahayokeya* species do not support the status of the *Gardnericypraea* as a subgenus of *Pahayokeya*.

The four species were also considered the root stock for the *Pahayokeya* genus, although all four species were restricted to the Myakka Lagoon System. However, Kissimmee is separated and isolated from Myakka by the massive Polk Peninsula to the west as well as the narrow, deep water Caloosahatchee and Loxahatchee Straits to the south. In addition, intracapsular direct development and the associated restricted migration may be inferred based on the sister genus, *Muracypraea* Woodring, 1957 and the Recent *Muracypraea mus* Linnaeus, 1758 complex. The absence of a viable path of migration into Kissimmee from Myakka means the status of the subgenus species as the root stock for the *Pahayokeya* genus, restricted to Kissimmee, is unsupported.

In summary, the features of the four species of the subgenera do support their reclassification as *Akleistostoma (Gardnericypraea)* species and they are reclassified as follows:

Unit 10	<i>Akleistostoma (Gardnericypraea) erici</i> (Petuch, 1998)
Unit 7	<i>Akleistostoma (Gardnericypraea) mansfieldi</i> (Petuch, 1998)
Unit 4	<i>Akleistostoma (Gardnericypraea) jenniferae</i> (Petuch, 1998)
Unit 3	<i>Akleistostoma (Gardnericypraea) buchecki</i> (Petuch and Drolshagen, 2011)

See Figure 3 for comparisons with *Pahayokeya penningtonorum*, type species of the genus.

True *Pahayokeya* species of the Piacenzian Pliocene, Tamiami Formation were confined to Kissimmee until the end of the Pliocene (Fruitville Unit 2 equivalent). The Early, Middle and Latest Gelasian Age, Early Pleistocene, saw low sea levels throughout southern Florida, facilitating the migration and emergence of *Pahayokeya* species to the south and west

southwest of Kissimmee in the Caloosahatchee Formation. The genus did not survive past the Latest Gelasian Age.

### Origins

At Sarasota, *A. rilkoii* resembles the older *Akleistostoma olssoni* Petuch and Drolshagen, 2011, but is stubbier and more rectangular while *A. (M.) juliagardnerae* and *A. (G.) buchecki* are most similar to the older *A. (G.) jenniferae* (Petuch, 1998). The former is a more rounded shell with less developed auricular flanges while the latter is a larger, more elongate shell. The *A. (P.) walleri* specimens share features of both Unit 4 *Paludacypraea* Petuch and Drolshagen, 2011, *i.e.* *cookei* and *fruitvillensis* Petuch and Drolshagen, 2011, but are larger, more elongate shells, with wider, more flaring apertures. Both *A. (S.) parodizi* and *S. cannoni* inhabited the sea grass beds associated with the pearly mussel beds (*Perna contradiana*). The former resembles the older *Siphocypraea (Seminolecypraea) grovesi* Petuch, 2004 while the latter is probably an offshoot of the *Seminolecypraea* Petuch and Drolshagen, 2011 subgenus, precursors of true *Siphocypraea* Heilprin, 1886. The origin of *C. sarasotaensis* is uncertain, but resembles the younger *Calusacypraea loxa* Petuch and Drolshagen, 2011. In contrast, *C. (M.) kelleyi* resembles the older *Calusacypraea (Myakkacypraea) myakka* Petuch, 2004 but is more fusiform (spindle-like) and has a much narrower aperture. Found in both the Sarasota and Golden Gate quarries, *P. ketteri* is most similar to the older *Pseudadusta metae* (Petuch, 1994) while *P. (B.) kalafuti* resembles the older *Pseudadusta (Bithloa) irisae* Petuch and Drolshagen, 2011.

At Kissimmee, *A. (O.) diegelae* resembles an extreme dwarf of the older *Akleistostoma (Olssonicypraea) bairdi* (Petuch, 1994). *Pahayokeya penningtonorum*, type of the genus,

is most similar to the older *Pahayokeya gabriellae* (Petuch, 2004) but is smaller, narrower and higher domed. Similar to *Pahayokeya basingerensis* (Petuch, 2004), *P. heimeri* is more oval and stumpier than the former. *Pahayokeya (Kissimmecypraea) leonardi* comes in two forms. The original description was based on the smaller form which, compared to *Pahayokeya (Kissimmecypraea) eddiematchetti* Petuch and Drolshagen, 2011, is average in size but is smaller than *P. (K.) eddiematchetti*, more oval, inflated with a more rounded base, narrower aperture and smaller and more pointed auricles. The larger form shares these features, but is larger and more elongate.

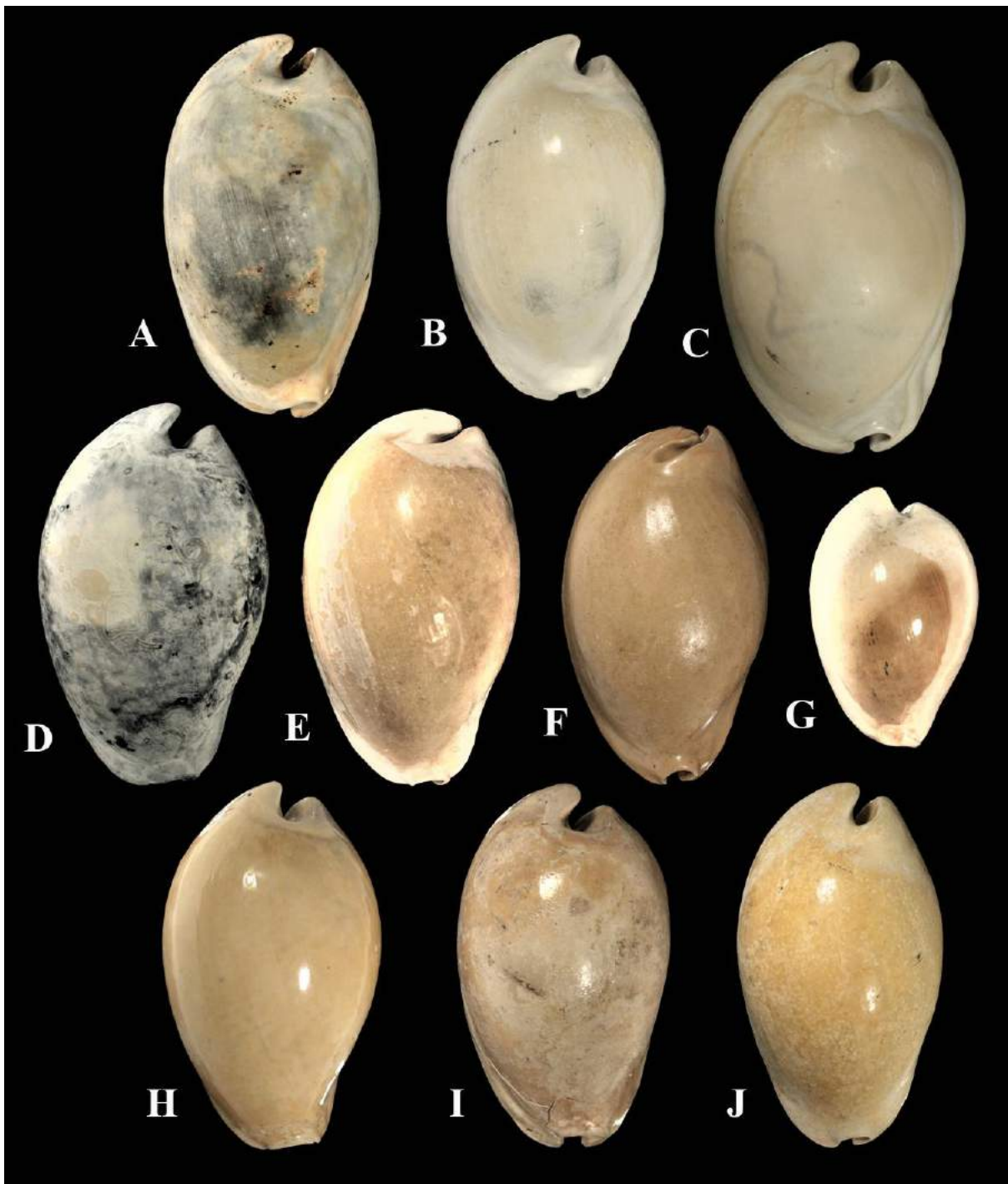
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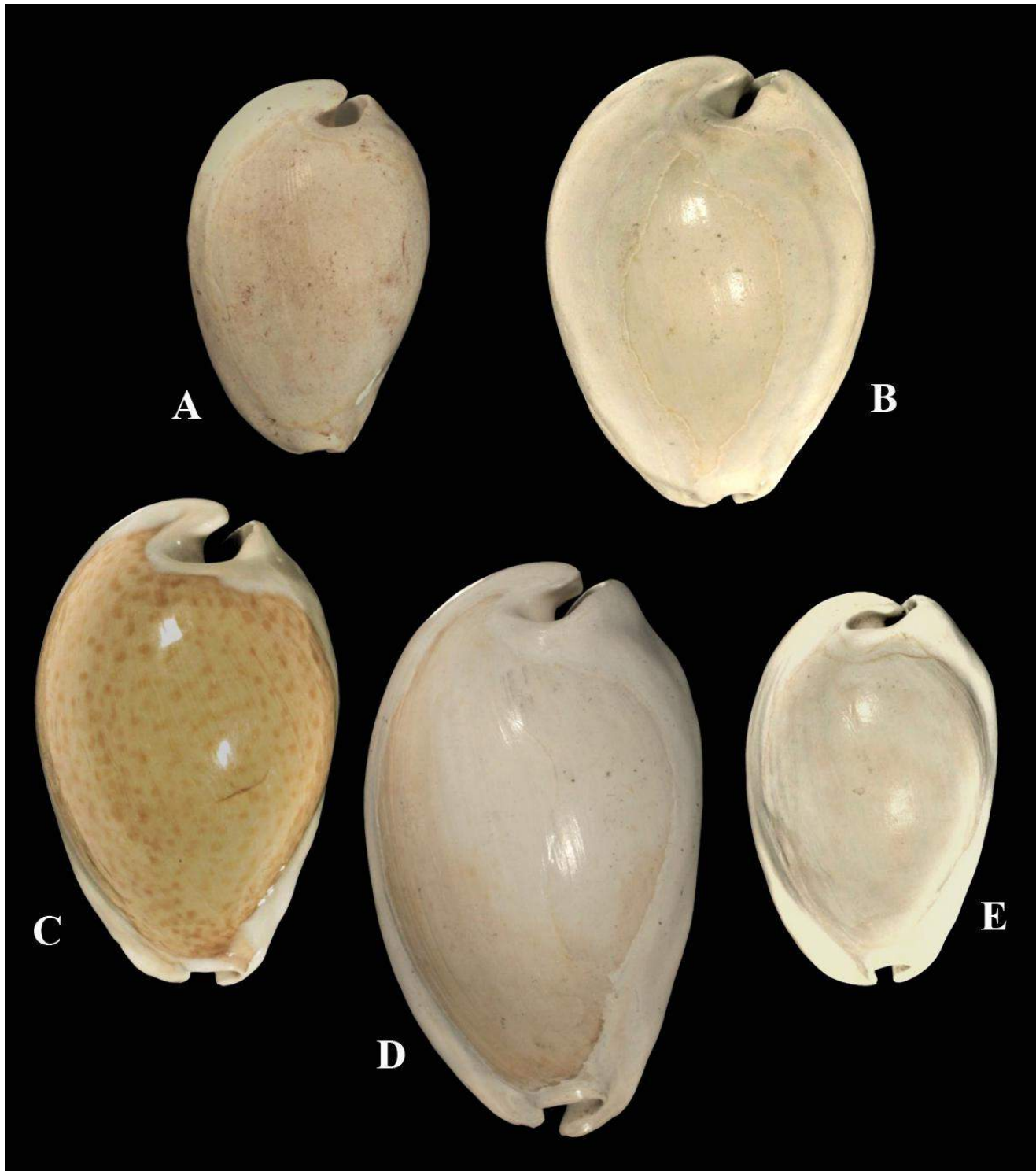
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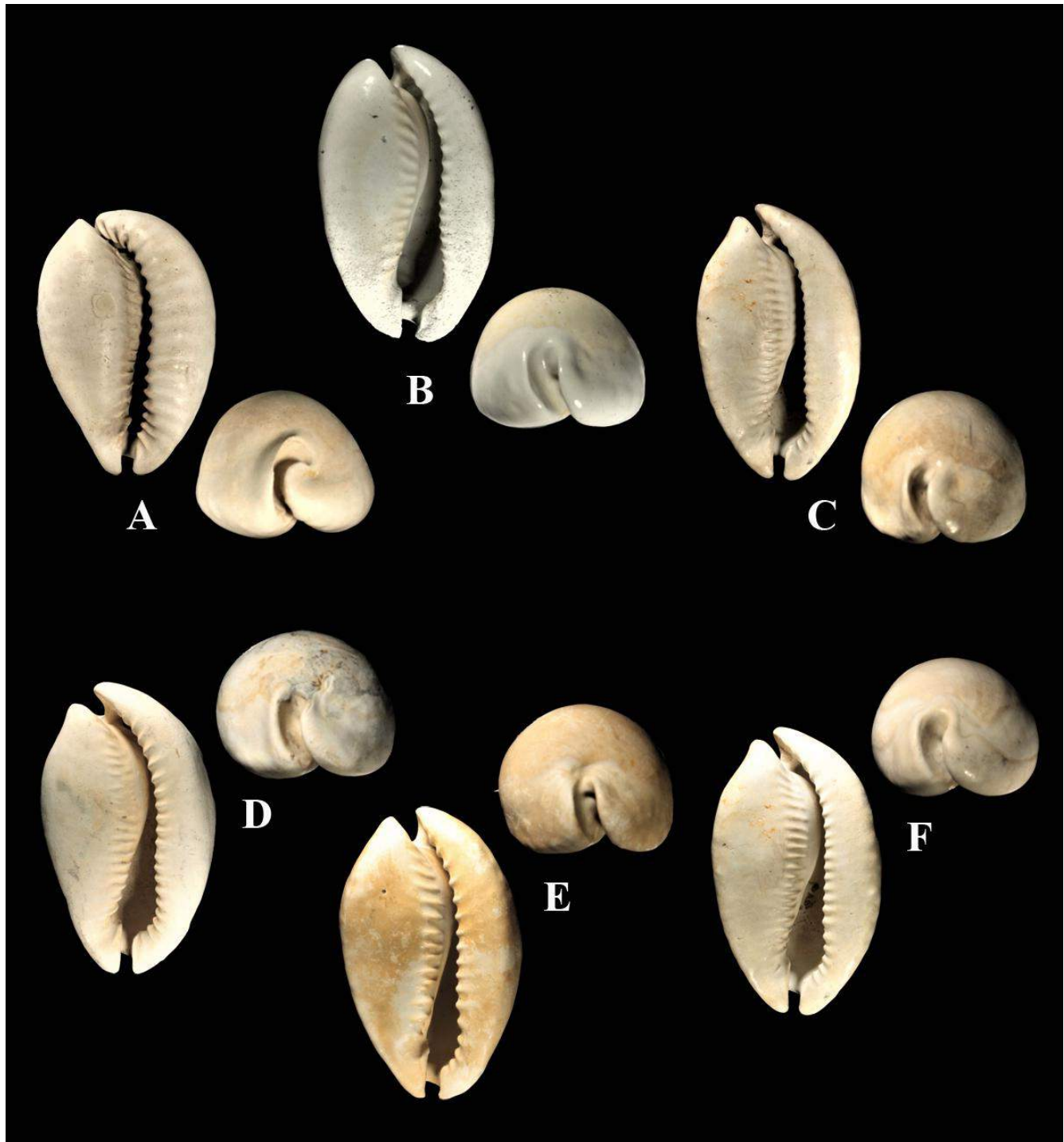


**Figure 1. Myakka Lagoon System, Sarasota (Unit 3).** A = *Akleistostoma rilkoii* (Petuch, 1998), length = 66.8 mm; B = *Akleistostoma (Mansfieldicypraea) juliagardnerae* Petuch and Drolshagen, 2011, length = 64.0 mm; C = *Akleistostoma (Gardnericypraea) buchecki* Petuch and Drolshagen, 2011, 79.4 mm; D = *Akleistostoma (Paludacypraea) walleri* Petuch and Drolshagen, 2011, length = 72.8 mm; E = *Siphocypraea cannoni* (Petuch, 1994), length = 74.5 mm; F = *Siphocypraea (Seminolecypraea) parodizi* Petuch, 1994, length = 67.9 mm; G = *Calusacypraea sarasotaensis* (Petuch, 1994), length = 44.4 mm; H = *Calusacypraea (Myakkacypraea) kelleyi* (Petuch, 1998), length = 58.4 mm; I = *Pseudadusta ketteri* (Petuch, 1994), length 54.3 mm; J = *Pseudadusta (Bithloa) kalafuti* (Petuch, 1994), length = 74.1 mm.



**Figure 2. Kissimmee River Valley restricted (Unit 3 equivalent).** **A** = *Akleistostoma (Olssonicypraea) diegelae* (Petuch, 1994, length = 42.8 mm; **B** = *Pahayokea heimeri* (Petuch and Drolshagen, 2011), length = 51.6 mm; **C** = *Pahayokea (Kissimmecypraea) leonardi* Petuch and Drolshagen, 2011, length = 58.5 mm; **D** = *Pahayokea (Kissimmecypraea) leonardi* Petuch and Drolshagen, length = 71.3 mm LARGE FORM; **E** = *Pahayokea penningtonorum* (Petuch, 1994), length = 49.8 mm.





**Figure 3. Subgenus (*Gardnericypraea*), *Akleistostoma* vs. *Pahayokea* Comparisons. A = *Pahayokea penningtonorum*, length = 47.7 mm (**Type of the genus**); B = *Akleistostoma carolinensis*, length = 60.3 mm (**Type of the genus**); C = *Akleistostoma* (*Gardnericypraea*) *erici* (Petuch, 1998), length = 75.9 mm; D = *Akleistostoma* (*Gardnericypraea*) *mansfieldi* (Petuch, 1998), length = 67.3 mm; E = *Akleistostoma* (*Gardnericypraea*) *jenniferae* (Petuch, 1998), length = 63.6 mm; F = *Akleistostoma* (*Gardnericypraea*) *buckecki* Petuch and Drolshagen, 2011, length = 79.4 mm.**