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The Fossil Cypraeidae of the Fruitville Member (Unit 4) and Kissimmee River Valley Equivalent, Tamiami Formation of Southern Florida: (Mollusca: Gastropoda: Cypraeidae)

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ABSTRACT The disappearance of all Pinecrest and equivalent Cypraeidae species from most of their habitats was caused by the circa 200,000 year cooling period in the mid Piacenzian Pliocene, c. 3.2-3.0 mya, and the associated significantly lower sea levels and dry terrestrial conditions in southern Florida. The cooling period was followed by a warming period, which resulted in the Tamiami Subsea being flooded to its maximum size and produced wide-spread tropical conditions throughout southern Florida, roughly similar to today's southwest Pacific. This resulted in the renewed radiation and speciation of the Cypraeidae populations. In the Myakka Lagoon System, the eight Pinecrest Member (Unit 7) Cypraeidae species in five genera were followed by ten new species in five genera which emerged in Fruitville (Unit 4) time. In the Kissimmee River Valley, the five Unit 7 equivalent species in three genera were followed by eight new species in three genera, which emerged in that area. The number of genera remains consistent at three with the only species previously assigned to *Pseudadusta* Petuch, 2004 placed into synonymy with *Akleistotoma bairdi* (Petuch, 2004). This represented a continuation of geographically separate, but parallel, evolutionary tracks.

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

Pinecrest Member Extinguished

The extinguishment of the Pinecrest Member and its Cypraeidae species was marked by a mid-Piacenzian cooling period of about 200,000 years, c. 3.2-3.0 million years ago ("mya"), which is reflected in Units 6 and 5 that mirrored Unit 9 and 8 conditions in the Myakka Lagoon System (Myakka), present day Sarasota area. (see Daughenbaugh, J.D., 2019, Festivus 51(1) and 51(2).) The reduced sea levels produced dry, terrestrial conditions throughout much of southern Florida. This is reflected in unconformities (missing layers or strata) in many of those areas. In both Myakka and Kissimmee this greatly constricted the sea grass and mud flat Cypraeidae habitats, resulting in the disappearance of all Pinecrest species. Isolated pockets undoubtedly remained and formed the basis for the radiation and speciation, which occurred during the subsequent Fruitville Member units of the mid to late Piacenzian.

Southern Peninsular FL (Fruitville Units 4)

The mid-Piacenzian, c. 3.0 mya, marked the commencement of the Fruitville Member of the Tamiami Formation. Following the end of

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Pinecrest time period, southern Florida commenced a warming trend that progressively produced the warmest and most tropical conditions of the entire Pliocene. This was manifested in the highest sea levels in the Tamiami Subsea, which encompassed Myakka, Kissimmee and the Everglades Pseudoatoll.

South of Myakka and Kissimmee, the Everglades pseudoatoll was home to the molluscan species that inhabited the tropical coralline Golden Gate Member of the Tamiami Formation. The pseudoatoll was U-shaped, open in the north, and bounded by coral reefs and coral reef tracts encompassing the present day Everglades on the east, south and west. (see Figure 1.) Experiencing periodic flooding and emergent events, the pseudoatoll grew in fits and starts but achieved its maximum development during Fruitville 4 time with coral species diversity and population densities at a level similar to today's southwest Pacific. It would remain separate from peninsular Florida until the Pleistocene when sediments would fill the remaining gaps. Today, the buried remnants along the rims of the reef tracts form the higher elevation areas adjacent to the Everglades. The southeastern coastal cities from Palm Beach to Miami rest on the underlying rim-like features. (see Daughenbaugh, J.D., Festivus 51(3) for full discussion and treatment.)

Fruitville and Contemporary Members, Tamiami Formation

In 1990, Waldrop and Wilson proposed the "Fruitville Formation" for the Pliocene sequence at Sarasota (Petuch Units 10-1) as most of the members of the Tamiami Formation lacked formal descriptions. Fruitville is a small town east of Sarasota, Florida. All units above Unit 11 at the APAC pit were included in the new formation and were put forward in replacement of the Pinecrest Member, which was then only broadly described. The authors' work was based on a biostratigraphic approach that created a proposed biozone.

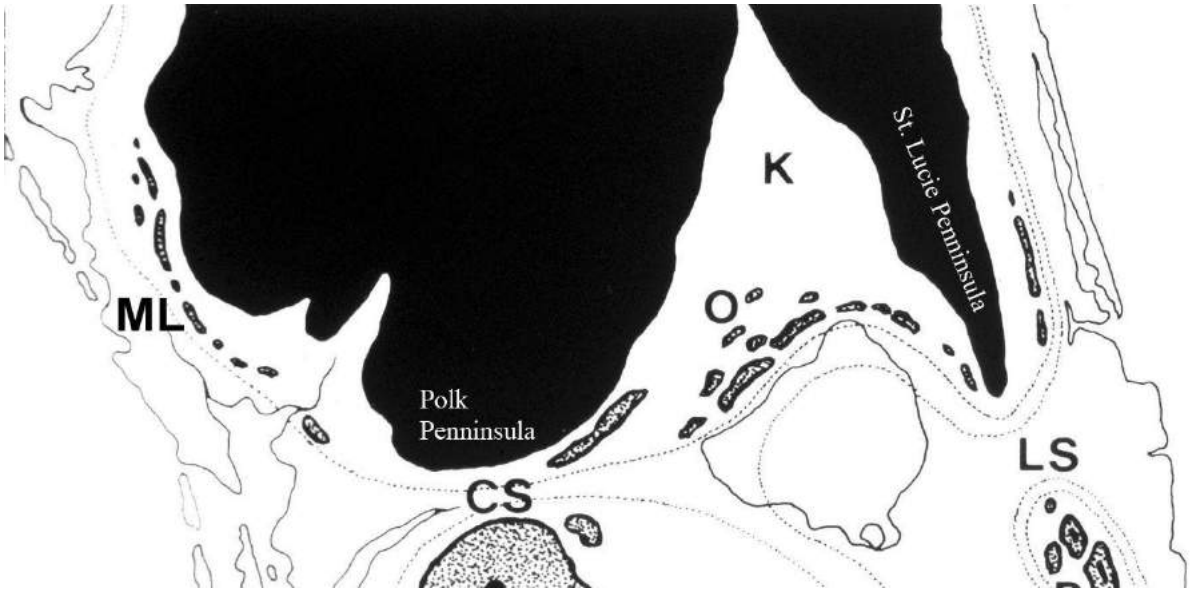

Figure 1. Map reflecting the Tamiami Subsea. ML = Myakka Lagoon System; K = Kissimmee Embayment; O = Okeechobee Patch Reefs: CS = Caloosahatchee Strait; LS = Loxahatchee Strait. Adapted from Petuch *et al*. 2018, figure 1.5 at p. 37.

Biostratigraphy relies on the correlation and assignment of relative ages of rock strata based on the fossil assemblages contained within the strata.

However, today, modern geology uses lithology (the physical characteristics of a rock unit) to identify individual formations and their members. Formations (aka geological formations), which are further divided into members, are the fundamental units of lithostratigraphy. Lithostratigraphy is based on the readily visible physical characteristics of rock strata or layers, not fossil assemblages. As such, Petuch assigned Units 9-5 at Sarasota to the Pinecrest Member as the lithology aligns with the Olsson and Petit (1964) description as refined by Missimer, T.M. (1992). Further, as "Fruitville Formation" had been used by a number of workers, including Emily Vokes, Petuch retained the name to differentiate the lithography of Units 4-2 at Sarasota as a member, *i.e.* the Fruitville Member.

Fruitville Member Beds

The Fruitville Member beds are composed of interbedded, *i.e.* alternating beds, of organic rich quartz sand, quartz sand with small amounts of clay and muddy quartz sand densely packed with fossil shells and fragments, many of which have taken on the coloration of the surrounding matrix. The alternating beds were produced by sea level variations that produced layers of unconformity (missing layers) in areas, which were emergent when sea levels dropped, especially during Units 3 and 2 time. The sea level changes also altered the depth of the remaining molluscan habitats. The Fruitville beds have thinner quartz sand beds that are muddier and contain more clay than Pinecrest beds.

Fruitville (Unit 4) Myakka Lagoon System

In the west, the prior Pliocene Cypraeidae habitats (Buckingham Unit 10 and Pinecrest Unit 7) were largely confined to sea grass beds with a small number of specimens exhibiting some black/blue staining characteristic of muddy, brackish habitats. However, by Fruitville Unit 4 time, Myakka, present day Sarasota region, was flooded producing what became the largest and best developed mangrove forests of the Tamiami Subsea. The mangrove forests formed a niche habitat along the coast line of the estuarine Myakka. These probably resembled similar forests in New Guinea and, along with associated intertidal mud flats and tidal channels, contained the richest estuarine molluscan fauna of the American Pliocene. The Fruitville basal Unit 4 is thickest and best developed at Myakka.

In the muddy peat layers at Sarasota, the most iconic of the Unit 4 Myakka habitats, darkly stained tannins leached from decaying vegetation in an oxygen poor, sulfuric environment. Small iron pyrite crystals (aka fool's gold) are often found attached to molluscan fossils and quartz sand grains. This is associated with brackish, swamp like muddy estuaries and coastal marshlands and produced many black, blue and/or tan stained fossil Cypraeidae specimens. Thus, the "Black Layer" designation. Fossil specimens recorded from such areas commonly exhibit such staining. For species confined to such habitats, Petuch proposed the subgenera *Akleistostoma (Paludacypraea)* Petuch and Drolshagen, 2011. Two Unit 4 species are assigned to the subgenera (see list in Table 1 below).

Separately, intertidal mud banks, adjacent to and encroaching on the mangrove jungles, provided the habitat for *Calusacypraea* Petuch, 2004 sp. (see below). In slightly deeper water

(1-3 m), mud bottoms and tidal channels hosted extensive beds of the small mactrid bivalve (estuarine associated) *Mulinia sapotilla* Dall, 1898. These were interspersed with sea grass beds in open areas along the edges of the banks and channels. These were inhabited by other Cypraeidae species, such as *Pseudadusta metae* (Petuch, 1994). Generally, these are not stained black/blue. However, some specimens occasionally exhibit such staining or tan/brown staining, suggesting they lived in close enough proximity to sometimes encroach on the Black Layer habitat.

Myakka Cypraeidae populations, which had been largely isolated in the Pinecrest saw cracks in this isolation. Several Unit 4 species have been reported from both Myakka and the Golden Gate of the Everglades Pseudoatoll in Lee and Collier Counties (see below). However, the neotenic Cypraeid genus *Calusacypraea* (Petuch, 1996) remained isolated in Myakka throughout Pinecrest and Fruitville times.

Fruitville (Unit 4) Kissimmee River Valley Equivalent

In the east, the Kissimmee Embayment and its southern sedimentary deposits formed a long and broad river valley (Kissimmee), which represented its southernmost extension. Following the 200,000 year cooling period that severely reduced molluscan habitats, these habitats were restored and reached their maximum expansion during Unit 4 time. Wide, shallow (1-5 meters deep) banks of compacted silica based river sediments, interspersed with tidal channels, dominated the central area within Kissimmee. The banks supported extensive sea grass beds that formed the habitats for several Cypraeidae populations.

As at Myakka, Kissimmee also hosted muddy estuarine and mangrove forest habitats. The associated mudflats were intertidal and served as the restricted habitat of the neotenic genus (juvenile characteristics retained in adults) *Okeechobea* Petuch, 2004. The species in the genus (see below) evolved along a geographically separate but parallel track with the Myakka *Calusacypraea* species. Near shore, intertidal mud flats also served as the habitat for *Akleistostoma (Ingramicypraea) cliffordi* Petuch and Drolshagen, 2011 and *Pahayokea gabriellae* (Petuch, 2004). The latter's broad and flattened shape was ideal for fine particulate mud habitats.

The Unit 4 equivalent sedimentary facies differ from the Pinecrest and Myakka. Consisting of muddy, organic rich sand packed with shell fragments, the facies lacked the high percentages of mud and clay present in the Pinecrest Unit 7 equivalent facies. Its organic rich, grayish sand also does not reflect the high sulfide content and pyrite crystals of Unit 4 at Myakka.

As the sedimentary facies formed a continuum throughout Units 4 and 3 equivalents, it is necessary to rely on Index Fossils in order to assign the Cypraeidae aggregations to the appropriate equivalent unit. Also inhabiting the sea grass beds were a number of shallow water bivalves which serve as Index Fossils. These included *Cardita seminolensis* Olsson, 1957, *Pleuromeris pitysia* (Olsson, 1967) and *Carditamera dasytes* Olsson, 1967 among others. These were recorded in the lowest Fruitville beds at Kissimmee (Unit 4 equivalent) and have also been recorded from Unit 4 at Sarasota. The Unit 4 equivalent Cypraeidae species were recorded among and adjacent to those beds.

Long thought to be isolated within the Kissimmee, two Unit 4 equivalent species have also been reported from the Golden Gate

Member, Bonita Springs, Lee County (see below).

Unit 4 Transition

The Unit 4 transition at Myakka and Kissimmee was marked by falling sea levels, resulting in reduced and altered habitats. At this time, 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. Altogether, 19 species in six genera have been collected in Fruitville Unit 4 deposits and its equivalent. (see Table 1 below)

Fruitville Member Species – Unit 4 (G = also reported from the Golden Gate):

Myakka Lagoon System (Sarasota) Unit 4:

Akleistostoma olssoni Petuch and Drolshagen, 2011
Akleistostoma (Mansfieldicypraea) macbrideae (Petuch, 1998)
Akleistostoma (Paludacypraea) cookei Petuch and Drolshagen, 2011
Akleistostoma (Paludacypraea) fruitvillensis Petuch and Drolshagen, 2011
Akleistostoma (Dallicypraea) williamdalli Petuch and Drolshagen, 2011
Siphocypraea (Seminolecypraea) grovesi Petuch, 1998 (**G**)
Pahayokea (Gardnericypraea) jenniferae (Petuch, 1998) **NOTE**
Calusacypraea tequesta (Petuch, 1996)
Calusacypraea (Myakkacypraea) myakka Petuch, 2004
Pseudadusta metae (Petuch, 1994) (**G**)

Kissimmee Embayment (Kissimmee Valley restricted) Unit 4 equivalent:

Akleistostoma (Ingramicypraea) cliffordi Petuch and Drolshagen, 2011
Akleistostoma (Olssonicypraea) bairdi Petuch 2004*****
Pahayokea rucksorum (Petuch, 2004) (**G**)
Pahayokea gabrielleae (Petuch, 2004) (**G**)
Pahayokea basingerensis (Petuch, 2004)
Pahayokea (Kissimmecypraea) eddiematchetti Petuch and Drolshagen, 2011
Okeechobea waldroni Petuch and Drolshagen, 2011
Okeechobea (Yeehawcypraea) matchetti Petuch and Drolshagen, 2011

*** Reclassification**
NOTE: The *Pahayokea* subgenus *Gardnericypraea* is under study.

Table 1. Fruitville Cypraeidae species in the Unit 4 transition at Myakka and Kissimmee.

Originally placed in the *Pseudadusta* Petuch, 2004 genus as *Pseudadusta judei* Petuch and Drolshagen, 2011, the Holotype of the *P. judei* was described as apical sulcus slightly curved, aperture narrow, becoming wider at the anterior end, posterior columellar teeth becoming obsolete. The specimen illustrated in Jewels of the Everglades (7.5, D, E) and the specimen illustrated in the 2011 Compendium of Florida Fossil Shells (4.29, G, H, I) wherein the species was originally described reflect these features. However, the *Pseudadusta* genus was described as apical sulcus simple slot-like, narrow aperture with strong dentition. The features of

the species do not align with the features of the *Pseudadusta* genus.

In contrast, the subgenus *Olssonicypraea* Petuch and Drolshagen, 2011 was described as "round-to-oval, flattened cowries with thickened margins and narrow apertures" (Petuch *et al.* 2018, p. 56). *Olssonicypraea* apertures do widen at the anterior end, but less than other *Akleistostoma* species. Both Figures 2.22, D, E, *A. (O.) bairdi* and 7.5, D, E, *P. judei*, illustrated in Jewels, exhibit the features of the subgenus *A. (Olssonicypraea)*. Both were collected in the Unit 4 equivalent of the Kissimmee. The referenced Figures show specimens that are light weight with dentition which is not fully developed. They accord with what would be expected in young, dwarf *A. (O.) bairdi*. As specimens mature, they become progressively more callous. Figure 4 herein illustrates this progressive callousity. Accordingly, the taxon is placed into synonymy with *Akleistostoma (Olssonicypraea) bairdi*.

As no other *Pseudadusta* species have been reported or recorded from Kissimmee, the genus appears to be restricted to Myakka and the Golden Gate Member of the Everglades Pseudoatoll. The latter are separated from Kissimmee 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 either an ancestor or successor *Pseudadusta* species or a viable path of migration into Kissimmee from known *Pseudadusta* areas means the presence of the genus *Pseudadusta* in Kissimmee is unsupported at this time.

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. Dr. Petuch is Professor Emeritus, Florida Atlantic University where he was a professor of geology in the Department of Geosciences.

Origins

At Myakka (Sarasota), with the exception of *P. (G.) jenniferae*, all Unit 4 species are associated with the estuarine environments of Myakka, some with the brackish, swamp like muddy estuaries and coastal marshlands and others with the adjacent sea grass beds. The few specimens collected of *P. (G.) jenniferae*, with its rarity and lack of black staining on specimens, suggest it probably inhabited slightly deeper water sea grass beds.

Akleistostoma olssoni and *A. (M.) macbrideae* appear as offshoots of *Akleistostoma floridana* (Mansfield, 1931). At Sarasota (also present in the golden Gate Member), *S. (S.) grovesi* is most similar to the older *Siphocypraea (Seminolecypraea) trippeana* Parodiz, 1988, its probable ancestor. *Pseudadusta metae* is most similar to the earlier *Pseudadusta hertweckorum* (Petuch, 1991) while *A. (D.) williamdalli* is a unique, highly derived species with both *Akleistostoma* and *Pseudadusta* features. Its speciation represents an adaptation to the estuarine Black Layer environment and it disappeared at the end of Unit 4 time leaving no successors. The *Paludacypraea* species (paluda is latin for swamp) shared the same estuarine environment as *A. (D.) williamdalli* with most species exhibiting the associated black staining. The *Paludacypraea*s' twisted columellar outline and pseudofossula projecting into the aperture are unique to these species, features not shared with any known ancestor. *Calusacypraea*

tequesta represents a more globose and rounded *Calusacypraea duerri* (Petuch, 1996) while the ancestor of *C. (M.) myakka* is not known.

At Kissimmee, *A. (I.) cliffordi* (confirmed as Unit 4 equivalent) is most similar to the older *Akleistostoma (Ingramicypraea) highlandensis* Petuch and Drolshagen, 2011, but more elongate. Similarly, *A. (O.) bairdi* presents as a slender and more pyriform, among other features, *Akleistostoma (Olssonicyprae) hughesi* (Olsson and Petit, 1964). *Pahayokea rucksorum* and *P. gabriellae* represent sympatric species, *i.e.* species descended from a common ancestor while inhabiting the same geographic region. The more globose, inflated and domed *P. rucksorum* inhabited turtle grass beds while *P. gabriellae* inhabited mud flats. Their ancestor and the ancestor to *P. basingerensis*, named for its type locality of Fort Basinger, Highlands County, are unknown, although the latter has also been recorded from Rucks Pit, Okeechobee to the north. *Okeechobea waldroni* is most similar to the older *Okeechobea osceolai* Petuch and Drolshagen, 2011, but is more elongate and cylindrical with a narrower aperture while *O. (Y.) matchetti* is much broader and more inflated than the older *Okeechobea (Yeehawcypraea) bartoni* Petuch and Drolshagen, 2011.

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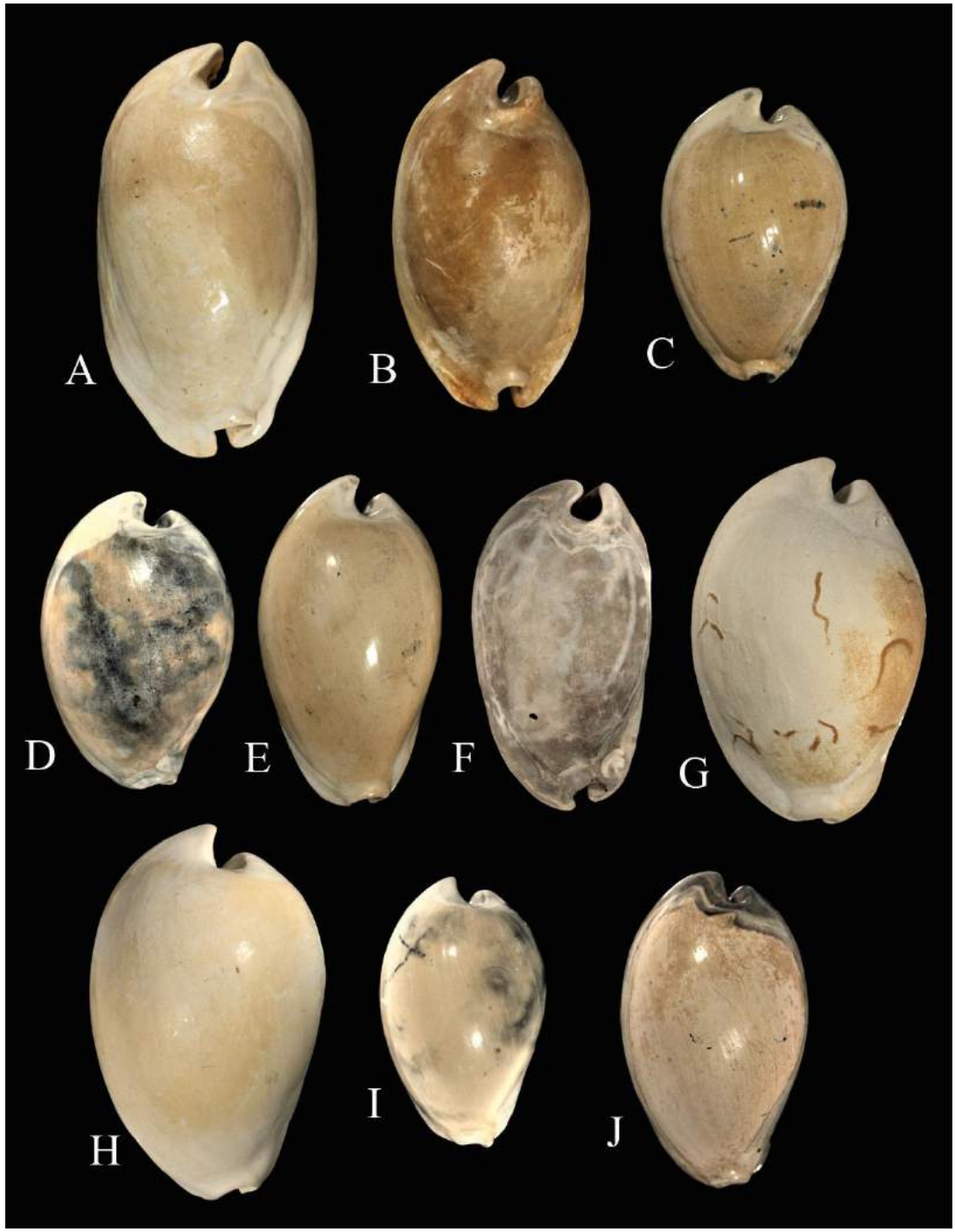

Figure 2. Myakka Lagoon System, Sarasota (Unit 4). **A** = *Akleistostoma olssoni* Petuch and Drolshagen, 2011, length = 84.0 mm; **B** = *Akleistostoma (Mansfieldicypraea) macbrideae* Petuch and Drolshagen, 2011, length = 72.2 mm; **C** = *Akleistostoma (Paludacypraea) fruitvillensis* Petuch and Drolshagen, 2011, length = 59.8 mm; **D** = *Akleistostoma (Paludacypraea) cookei* Petuch and Drolshagen, 2011, length = 60.1 mm; **E** = *Akleistostoma (Dallicypraea) williamdalli* (Petuch and Drolshagen, 2011), length = 67.3 mm; **F** = *Siphocypraea (Seminolecypraea) grovesi* Petuch, 2004, length = 63.8 mm; **G** = *Pahayokea (Gardnericypraea) jenniferae* (Petuch, 1998), length = 74.3 mm; **H** = *Calusacypraea tequesta* (Petuch, 1996), length = 72.3 mm; **I** = *Calusacypraea (Myakkacypraea) myakka* Petuch, 2004, length = 55.0 mm; **J** = *Pseudadusta metae* (Petuch, 1994), length = 64.5 mm.

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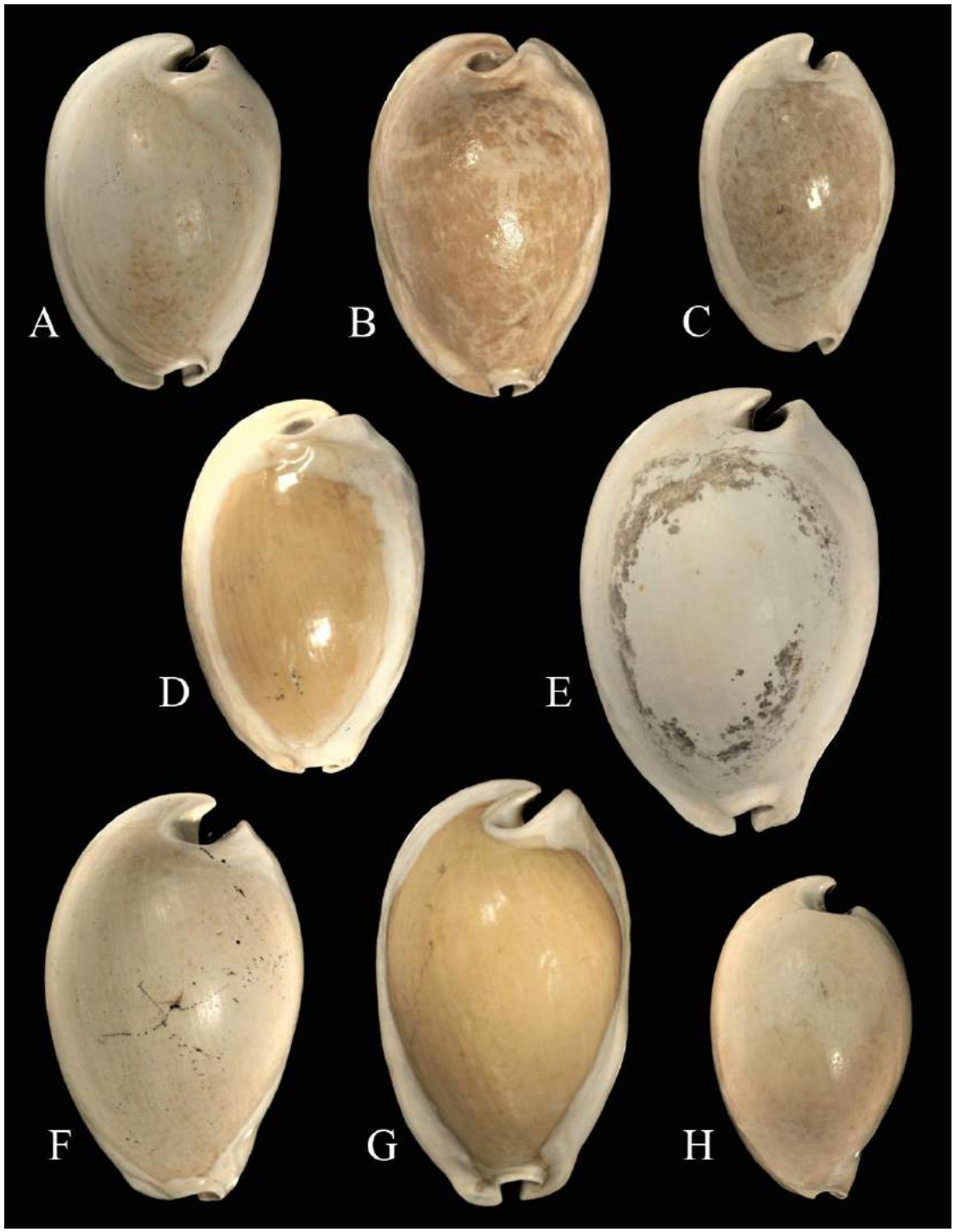

Figure 3. Kissimmee River Valley restricted (Unit 4 equivalent). A = *Akleistostoma (Olssonicypraea) bairdi* Petuch, 2004, length = 61.6 mm; **B** = *Pahayokea rucksorum* (Petuch, 2004), length = 59.7 mm; **C** = *Akleistostoma (Ingramicypraea) cliffordi* Petuch and Drolshagen, 2011, length = 53.2 mm; **D** = *Pahayokea gabrielleae* (Petuch, 2004), length = 61.7 mm; **E** = *Pahayokea basingerensis* (Petuch, 2004), length = 78.5 mm; **F** = *Okeechobea waldroni* Petuch and Drolshagen, 2011, length = 67.1 mm; **G** = *Pahayokea (Kissimmecypraea) eddiematchetti* Petuch and Drolshagen, 2011, length = 74.8 mm; **H** = *Okeechobea (Yeehawcypraea) matchetti* Petuch and Drolshagen, 2011, length = 55.9 mm.

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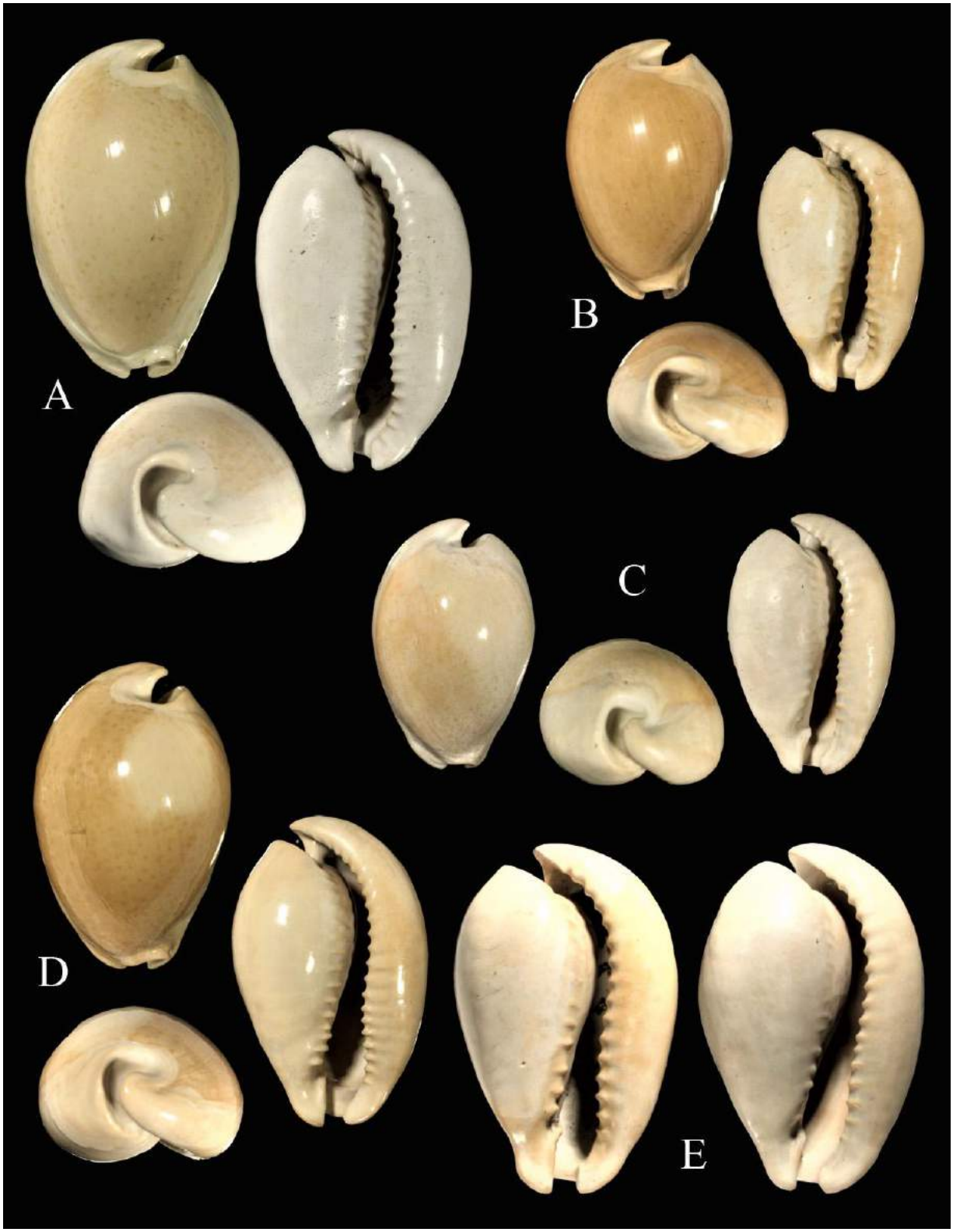

Figure 4. ***Akleistostoma (Olssonicypraea) bairdi*** **Comparisons. A** = 61.5 mm; **B** = 47.6 mm; **C** = 47.5 mm (aka *Pseudadusta judei* Petuch and Drolshagen, 2011); **D** = 56.1 mm; **E** = basal comparisons, left = *A. (O).) bairdi* vs. right *A. (O.) bairdi* (aka *P. judei*).