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# Educational opportunities provided by a resedimented and bioeroded bivalve steinkern from the Cenozoic of western Florida, USA

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**Abstract**

A venerid (*Mercenaria*?) bivalve fossil, recently collected as an allochthonous bioclast from a beach in Florida, USA, presents an opportunity to discuss aspects of paleontology and sedimentology that may be useful to educators involved in the geological and/or biological sciences. The specimen, which was transported to the shore following a storm event, is preserved as an internal mold (steinkern) that is completely penetrated by the bioerosional ichnogenus *Gastrochaenolites*. This otherwise inconspicuous fossil records evidence of a surprisingly complicated history, including shell burial and infilling, lithification of infilling sediment, dissolution of shell, incorporation into a lithified bioclastic sedimentary layer, boring through the layer by a different bivalve, erosion by storm currents, and transportation onto the beach. The occurrence of this specimen as an allochthonous pebble illustrates an instance in which trace fossils can be transported and highlights the significance of storm events in facilitating resedimentation of bioclastic material in carbonate settings.

*Key words*: Mollusca, ichnology, geological education, bioerosion, taphonomy

## 1. Introduction

Bivalve shells are ubiquitous bioclasts on numerous beaches throughout the Caribbean and Gulf Coast region, including southern Florida, USA (e.g. Hartmann, 2006). To a geological and/or biological educator, the commonness of these shells carries advantages and disadvantages. On the advantageous end, large collections can be readily obtained and used for various paleoecological, taphonomic, and sedimentological analyses. Further, shells belonging to particular taxa can be observed in a variety of physical states. On the disadvantageous end, specimens that are inconspicuous and/or poorly preserved (using criteria such as valve articulation, shell surface ornamentation, color retention, extent of abrasion and encrustation, etc.) are easily overlooked and typically left uncollected (see further discussion in Donovan, 2011a). This collection issue is true not only for Recent shells, but also for fossil material that can accumulate on modern beaches.

The purpose of the present study is to describe one such seemingly 'unremarkable' bivalve fossil that was collected from a modern Florida beach. Although it does not display overt or dramatic characteristics that would normally warrant collection, careful inspection of its properties reveals multiple features that are worth comment. More importantly, the use of a less-than-spectacular specimen as the basis for illustrating physical processes operating in a modern environment and the geological processes associated with the preservational history of the specimen provides educational opportunities that can be replicated with similar readily collected material. The specific aspects that can be emphasized by educators will vary with audience, but there is sufficient basis for using this as a simple case study in the use of a beach-collected bivalve fossil for informative purposes.

## 2. Materials and methods

The specimen described here was collected from the beach on the western (seaward) side of Honeymoon Island, a barrier island separated by Saint Joseph Bay from the mainland city of Dunedin, Pinellas County, southwestern Florida, USA (N28.062522°, W82.831091°), in August 2024. It was picked up as a loose bioclast following a major storm that brought numerous large particles to the beach from seaward areas.

Given the allochthonous nature of the bioclast, it is impossible to state with certainty which stratigraphic unit yielded the bivalve fossil. The most likely source is the Tampa Member of the Arcadia Formation (Hawthorn Group), which is either Early Miocene (Scott, 1988; Petuch and Berschauer, 2021, p. 34) or late Oligocene-early Miocene (e.g. Jones, 1997). The Tampa Member comprises a mollusk-rich carbonate unit (Scott, 1988; Jones, 1997); it is exposed on the nearby mainland. More importantly, it is present in local offshore areas, as it was dredged in 1969 to provide the southern portion of the island with material for beach replenishment and for an associated causeway (Wright and O'Donnel, 1973). However, silicification of fossils and fossil-nucleated chert nodules are common in the Tampa Member (e.g. Scott, 1988), but there are no signs of silica replacement on the specimen described here. Other lithostratigraphic units that are considered possible, but less likely, sources include the Oligocene Suwannee Limestone and the Eocene Ocala Limestone, both of which yield similarly preserved bivalve fossils (Jones, 1997; Petuch and Berschauer, 2021). These units are exposed further to the north of Honeymoon Island and would have required greater transport to reach the collection site. However, these units may have been contributors of allochthonous bioclasts if the storm-associated currents displayed a more shore-parallel orientation during some phase of the storm, flowing roughly southward along the coast.

## 3. Description of material

The material consists of two entities, potentially separated in origin by millions of years: the venerid body fossil and the macroboring *Gastrochaenolites* that penetrates it (see also Donovan, 2014). The bivalve fossil is whitish-gray in color, measuring 63 mm in anterior-posterior length, 58 mm in dorsal-ventral height, and 59 mm in thickness (Fig. 1). It is preserved as a relatively complete internal mold (steinkern) with no adhering matrix sediment and very little remnant shell material, which is distributed in small, thin, irregular patches that show few details of growth lines and shell texture (Fig. 1C). The infilling material consists of white micrite (Fig. 1). The fact that the valves are articulated prevents observation of the hinge teeth. Given the absence of many diagnostic features, this specimen cannot be identified to genus and is listed as Veneridae gen. et sp. indet., although the overall shape is suggestive of *Mercenaria*. The internal mold preserves both valves, which are fully articulated and complete, and there is no evidence for compression (Fig. 1C), collectively suggesting lithification of infilling micrite shortly after burial.

At 12 mm from the ventral edge of the shell, the outer margin of a boring is located (Fig. 1). This boring is attributable to the ichnogenus *Gastrochaenolites*, which is nearly always produced by a range of endolithic bivalves (but see Bromley, 2004, p. 462), and is club- or flask-shaped, with a narrower apertural end and an expanded, rounded distal chamber (Kelly and Bromley, 1984). This ichnogenus is common throughout the Caribbean region as both fossils and subfossils (e.g. Donovan and Hensley, 2006) and this is most likely the case for the Gulf Coast as well. The present *Gastrochaenolites* is incomplete, being manifest as a cylindrical hole that

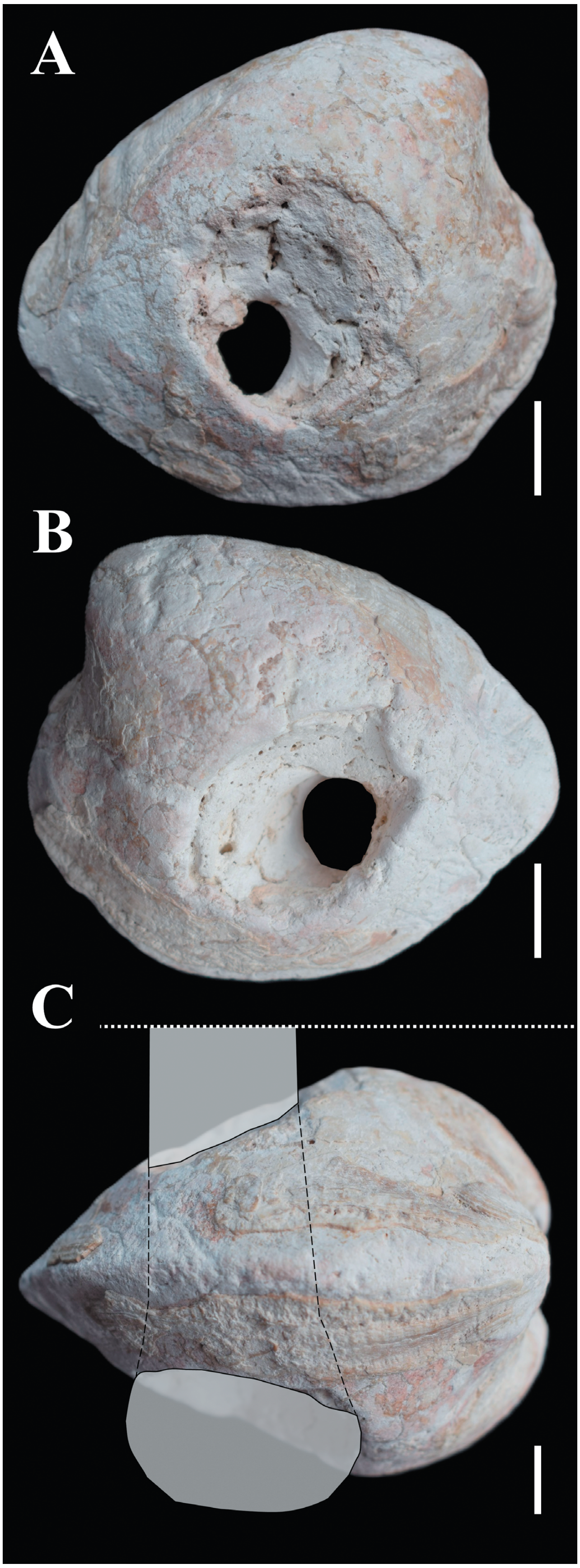


**Fig. 1.** Internal mold of a venerid bivalve (*Mercenaria*?) that is completely penetrated by a *Gastrochaenolites* boring. Specimen is held in the State University of New York, Center for Earth and Environmental Science paleontological teaching collection. A. View of right valve, which contains the upper, narrower portion of the boring. B. View of left valve, which contains the lower, wider portion of the boring. This valve would have been downward-facing during final burial. C. Cross-sectional view of specimen, demonstrating the position at the time of boring. A theoretical position of the seafloor is marked by the horizontal dashed line and the bivalve would have been incorporated into a limestone layer. The shaded areas and vertical dashed lines provide a crude outline of the boring. Scale bars = 10 mm.

completely penetrates the internal mold, cutting through both valves in an orientation that is perpendicular to the dorsal-ventral axis (Fig. 1C). Due to this incompleteness, it can only be identified to ichnogenus, which is common for borings preserved in allochthonous bioclasts collected from beaches (e.g. Donovan, 2011c, 2013b, 2024). The narrow end of the boring, situated on the right valve, measures 21 mm in maximum diameter (Fig. 1A) and the broad end, situated on the left valve, measures 31 mm in maximum diameter (Fig. 1B). These dimensions are comparable to *Gastrochaenolites* reported from other macrofossil substrates (e.g. nautiloid cephalopod internal mold: Jagt et al., 2015, p. 77; irregular echinoid: Jagt et al., 2018, p. 267), although these measurements may not be significant, as the dimensions of the boring will reflect the ontogenetic state of the borer. There are no encrusting organisms on the exterior of the internal mold nor on any remnant shell material and there are no encrusting organisms within the boring.

## 4. Discussion

The educational opportunities presented by this fairly inconspicuous fossil specimen come from the fact that a relatively complicated and interesting preservational history is needed in order to allow this bivalve to be collected on a modern Florida beach. The sequence of events is the following: (1) death of the bivalve and decay of internal soft tissues, although the ligament holding the valves together remained intact; (2) reorientation of the empty shell into a *post-mortem* orientation in which the left valve was flat on the seafloor (Fig. 1C); (3)burial of the shell; (4) infilling of the empty shell with fine micritic sediment, presumably through cracks or bioerosion structures in the shell; (5) lithification of the infilling micrite; (6) dissolution of the shell surrounding the internal mold; (7) cementation of the internal mold, along with surrounding material, into a layer of limestone; (8) boring through the layer by an endolithic bivalve; (9) erosion of the limestone layer by a storm event, which liberated the internal mold from surrounding sedimentary rock; and (10) transportation of the loose, bored internal mold to the beach by storm currents. Donovan and Jagt (2013, p. 138–139; see also Jagt et al., 2015, p. 76–77) described an internal mold of a Cretaceous cephalopod not recovered as a beach clast and interpreted an identical taphonomic history for steps not related to transport to a beach. It is possible that some events may have occurred in a slightly different order than that listed above, but all ten steps are necessary in order to generate the scenario in which the specimen was discovered in its present taphonomic state as an allochthonous beach pebble.

Discovery of a fossil similar to the present example can generate stimulating and informative discussions when incorporated into educational excursions. The sequence of events associated with specimens can be reconstructed and debated—ideally upon collection while in the field—using basic logical principles (such as cross-cutting relationships) and the specific taphonomic features observed. Aspects related to geological context (e.g. potential source units for specimens, features related to burial and exhumation), organismal biology and ecology (e.g. contrasting factors affecting epibenthic vs. endobenthic forms, ecological components of bioerosion), and fossilization processes (e.g. different preservational pathways for moldic vs. non-moldic material, taphonomic significance of the location of encrusters) can be discussed. Such material also presents a real-world scenario in which the principle of multiple working hypotheses can be directly applied; for example, applying parallel consideration of whether the boring was produced before vs. after dissolution of the shell material. More broadly, there is educational value in the concept that more heavily altered fossils and subfossils can provide more historical information than the pristine specimens that typically attract the most attention and are collected most frequently.

This specimen also highlights two additional areas of educational value. First, it illustrates the concept that trace fossils are capable of being transported. Although most softground ichnofossils are generally discovered at the site of original formation, bioerosional ichnotaxa are readily collected as products preserved within allochthonous particles (see excellent discussions in Donovan et al., 2018, p. 12–13; Donovan, 2024). The ichnological literature contains diverse examples of borings discovered in transported lithic (e.g. Donovan, 2011b, 2011c, 2017; Donovan and Fearnhead, 2017; Donovan et al., 2018), xylic (e.g. Plint and Pickerill, 1985; Savrda et al., 1993; Donovan, 2013b; Donovan and Isted, 2014), and—as with the present specimen—bioclastic (e.g. Donovan and Lewis, 2010, 2011; Donovan, 2013a; Donovan and Pawson, 2013; Donovan et al., 2018) particles; even archaeological artifacts (e.g. Sacco Perasso et al., 2022) and unknown materials (Donovan and Ewin, 2018) have been documented as substrata for transported borings. The material described here provides a useful example of an ichnofossil that provides important paleoenvironmental and paleontological information, but also some additional challenges due to being physically displaced.

The second indirect instructional opportunity involves the process that allowed the fossil to be dislodged from its former sedimentary layer and transported onto the beach: a storm event. Storm currents readily transport coarse bioclastic particles landward (Aigner, 1985), resulting in shell accumulations on beaches (e.g. Boyajian and Thayer, 1995; Flessa, 1998; for an example of bioeroded shells transported from a pavement to the beach, see Donovan, 2019). This phenomenon is well known by beachcombers (e.g. Donovan, 2011a; Trewhella and Hatcher, 2015), and sedimentological studies have documented the strong effects of storms on controlling deposition along the carbonate-dominated coasts of southern Florida (Aigner, 1985; Risi et al., 1995). The large size and well-lithified sedimentary infill comprising the venerid internal mold demonstrates the strength of currents that would have been needed to erode the limestone layer containing the fossil and transport it shoreward to be deposited at the beach. This not only facilitates discussion of the important role(s) of episodic high-energy events in controlling the sedimentary history of carbonate-dominated environments, but also allows introduction to the concept of resedimentation—that is, that an important difference exists between 'burial' and 'final burial' in the history of a particle or fossil.

## 5. Conclusions

A noteworthy venerid bivalve fossil, preserved as an internal mold and discovered as an allochthonous bioclast on a southern Florida beach, presents a valuable educational opportunity. The lithified micritic infill serves as a substrate for the boring *Gastrochaenolites*, allowing both body and trace fossils to be represented in the same specimen. Although it does not display properties typically associated with exceptional preservation, the state and context of the material requires a complex, complicated history. The sequence of events can be interpreted and used to illustrate biological, geological, and general principles to a variety of audiences. This specimen can also serve to facilitate discussion of the important role of storm events in carbonate depositional environments and exemplify transportation of ichnofossils. More broadly, this case study demonstrates the instructional value of fossils and subfossils that are readily overlooked and typically left uncollected in favor of more complete or unaltered specimens; in many cases, inconspicuous, poorly preserved, or seemingly unremarkable fossils can be the most informative.

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