

ADDITIONAL ECHINODERMS FROM THE PCS (LEE CREEK) PHOSPHATE MINE, NEAR AURORA, BEAUFORT COUNTY, NORTH CAROLINA

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ABSTRACT

Three recently discovered echinoids, *Arbacia* sp. cf. *A. sloani* (Clark in Clark and Twitchell), *Encope macrophora* (Ravenel), and *Agassizia scrobiculata* Valenciennes, and one partial ophiuroid arm, family Ophiuridae, from the PCS Phosphate (Lee Creek) Mine, near Aurora, Beaufort County, North Carolina, are herein reported. The occurrence of these echinoderms supplement our knowledge of the taxa found in the mine.

INTRODUCTION

Kier (1983) identified five species of echinoids from the Lee Creek (= PCS) Phosphate Mine: *Abertella aberti* (Conrad, 1842) from the Middle Miocene Pungo River Formation; *Echinocardium kelloggi* Kier, 1983, *Psammechinus philanthropus* (Conrad, 1843), and *Arbacia improcera* (Conrad, 1843) from the Lower Pliocene part of the Yorktown Formation; and *Mellita* sp. cf. *M. acclinensis* Kier, 1963 and *A. improcera* from the Pliocene-Pleistocene Croatan (equals James City Formation used herein). Echinoids (spines and pieces of tests) are quite common in the mine spoil piles but the vast majority of these are too fragmentary for identification. The most easily identifiable remains are of the sand dollar *Mellita* sp. cf. *M. acclinensis*, but even for this species near-complete specimens are scarce. Recently, collectors found and donated to the North Carolina Museum of Natural Sciences, three species of echinoids not discussed by Kier (1983): *Arbacia* sp. cf. *A. sloani*, *Encope macrophora* (Ravenel, 1842), and *Agassizia scrobiculata* Valenciennes, 1846. These specimens, along with a

partial ophiuroid arm, representing the first Ophiuridae from this locality, are reported here. Together, with the echinoids documented by Kier (1983), these specimens give a more accurate account of the echinoderms found in the mine.

GEOLOGICAL SETTING

The PCS Phosphate (Lee Creek) Mine is located in Beaufort County, North Carolina, about eight km north of the community of Aurora. To gain access to the ore (which lies approximately 30-35 m below sea level) the top 10 m or so are removed using a bucket-wheel excavator and transported on a conveyor belt to a previously mined pit. The next 20-25 m are removed by large electric draglines and piled in the immediately previous cut (McLellan, 1983). This "topside-down" process results in the older sediments generally being placed on top of younger sediments in spoil piles; however mixing inevitably occurs. Once the equipment is removed to safe distances, fossil collectors are allowed to hunt the spoil piles under tightly regulated conditions. The 25 m of spoil contains the James City Formation (formerly known as the Croatan Formation), various levels of the Yorktown Formation, and the top level of the Pungo River Formation (Gibson, 1983) (Figure 1).

The Late Pliocene–Early Pleistocene James City sediments contain primarily invertebrate remains, including corals (e.g., *Septastrea*), mollusks (mostly extant subtropical species) (Ward and Blackwelder, 1987), arthropods, and bryozoans. Echinoid spines and test fragments are very common, including *Mellita* sp. cf. *M. acclinensis* and *Arbacia improcera* (Kier, 1983).

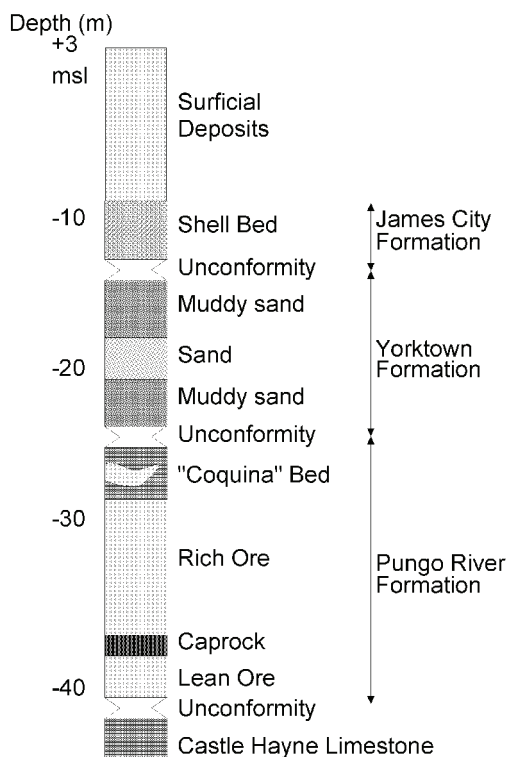


Figure 1: Simplified stratigraphic column of the PCS Phosphate (Lee Creek) Mine, modified from Riggs et al., 2000.

Vertebrate remains are rarely encountered but include shark teeth from species such as *Carcharodon carcharias* and *Galeocerdo cuvier* (Purdy et al., 2001).

The lower unit of the Yorktown Formation occurs at the Miocene–Pliocene boundary. In the mine, the Yorktown is particularly rich in vertebrate remains, including fish, marine mammals, and birds. Characteristic mollusks are *Chesapecten* and *Ephora* (Gibson, 1987; Wilson, 1987). Echinoids include *Echinocardium kelloggi*, *Psammechinus philanthropus*, and *Arbacia improcera* (Kier, 1983).

The oldest unit commonly encountered in the mine is the Middle Miocene Pungo River Formation. This unit is also rich in vertebrate remains, especially shark teeth. Mollusks are mainly moldic. Kier (1983) attributed remains of *Abertella aberti* to the Pungo River Formation at Lee Creek (PCS) Phosphate Mine but provided no illustration and implied that only

fragments were found. To our knowledge, no complete or near-complete echinoid remains have been found in Pungo River spoils.

SYSTEMATIC PALEONTOLOGY

All figured specimens are housed at the North Carolina Museum of Natural Sciences (NCSM), Raleigh, North Carolina.

Class	STELLEROIDEA Lamarck, 1816
Subclass	OPHIUROIDEA Gray, 1840
Order	OPHIURIDA Müller and Troschel, 1840
Family	?OPHIURIDAE Lyman, 1865

Material — One partial arm (NCSM 9811: Figure 2.1 - 2.3).

Measurements — Length 18.2 mm, width 7.8 – 6.5 mm tapered end to end, height 5.4 – 4.7 mm tapered end to end.

Description — Arm fragment triangular in cross section. Dorsal shield plates single, moderately curved, parallelogram shaped, 5.7 mm long, 1.8 mm wide. Lateral shield plate single, strongly curved, 4.1 mm high, 1.8 mm wide with curved protuberance on ventral end in contact with ventral shield plate. Ventral shield plate flat, 3.5 mm long, 1.2 mm wide, tapered on both ends and adjoining lateral plate protuberance. Dorsal shield forms vertebrae with neural hole in cross section.

Occurrence — Spoil piles, Yorktown Formation (Lower Pliocene), PCS Phosphate (Lee Creek) Mine, near Aurora, Beaufort County, North Carolina.

Discussion — Records of Pliocene asteroids or ophiuroids from the southeastern United States have been very limited (Portell and Oyen, 2001). Jones and Portell (1988) reported *Heliasaster microbrachius* Xantus, 1860 from the Tamiami Formation of southeastern Florida. To this, Oyen and Portell (2001), added *Luidia* sp. and an unknown ophiuroid from the same deposit. The ophiuroid, although complete, was

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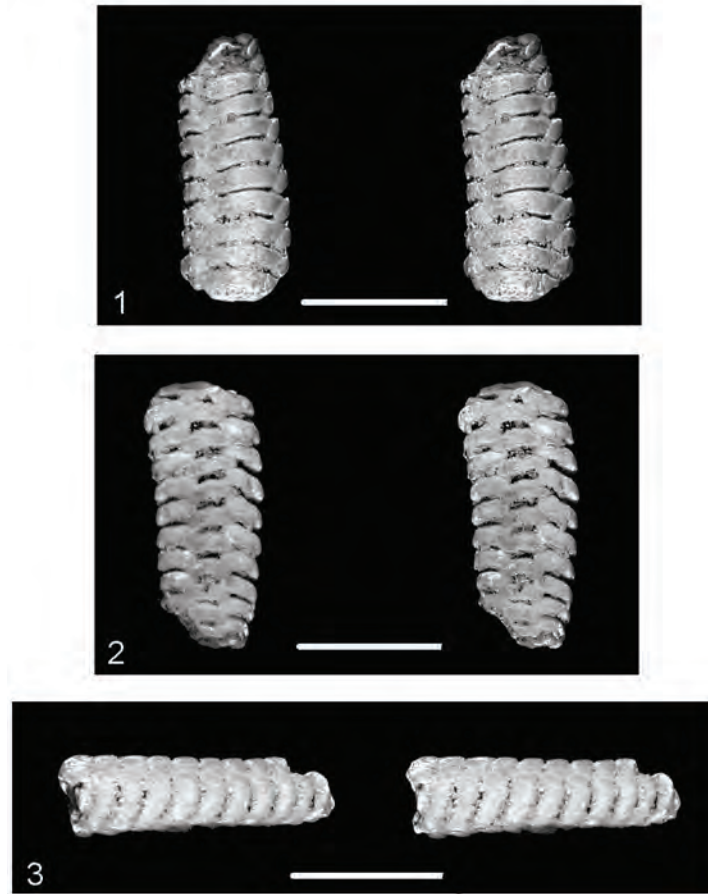


Figure 2: Stereo pairs of NCSM 9811, Ophiuridae (partial arm); 2.1 dorsal view, 2.2 ventral view, 2.3 lateral view. Scale bars = 10 mm.

highly recrystallized thus precluded identification. The discovery of a partial ophiuroid arm from the Yorktown Formation in the PCS Phosphate Mine is a welcome addition to the poorly known asteroid and ophiuroid fauna of the southeastern United States. Because this specimen is a partial arm, and comparative material is limited, it is unwise to attempt generic identification. However, as this partial arm is stout, tapering, and with short vestigial spines, characteristics of the family Ophiuridae as described by Spencer and Wright (1966), we assign this specimen to the family ? Ophiuridae. We report the occurrence with hope that other researchers may be encouraged to look for and identify more material from this understudied group.

Class ECHINOIDEA Leske, 1778
ORDER ARBACIOIDA GREGORY, 1900
Suborder ARBACIINA Gregory, 1900
Family ARBACIIDAE Gray, 1855
Genus *Arbacia* Gray, 1835
Species *Arbacia* sp. cf. *A. sloani* (CLARK IN CLARK AND TWITCHELL, 1915)

Material — Two specimens: 1 complete test (NCSM 9715: Figure 3.1 - 3.3), 1 broken test (but glued), portion of peristomal region miss-

ing (NCSM 9716: Figure 4.1 - 4.3)

Measurements —

Measurements in mm	NCSM 9715	NCSM 9716
Diameter	29.5	39.0
Height	15.8	22.5
Diameter of peristome	14.5	16.2
Greatest width of ambulacrum	6.1	9.0
Height of interambulacral plate at ambitus	2.9	3.2
Width of interambulacral plate at ambitus	5.7	7.0
Greatest width of apical system	9.1	10.7

Description — Test medium size, horizontal diameters 29.5 mm and 39.0 mm; moderately high, height 54-58 percent of diameter.

Apical system — Dicyclic, more visible in NCSM 9715 than NCSM 9716 due to cemented grains on test of NCSM 9716. Oculars small, exsert, with one imperforate tubercle: genital plates large, pentagonal, rugose with genital pore toward adoral point.

Periproct — Roughly diamond shaped, elongate from interambulacra 3 to 1.

Ambulacra — Narrow, regularly expanding to maximum width, approximately one-half width of interambulacra, at ambitus, maintaining nearly maximum width to peristome; poriferous zones relatively straight from apical system to near margin. Pore pairs below ambitus in oblique groups of three. Tubercles generally absent adapically, increasing in number and size to large tubercles in offset pairs adorally. Number of tubercles varies from 17 in 29.5 mm diameter specimen to 25 in 39.0 mm diameter specimen. One large pit in each ambulacrum near peristome.

Interambulacra — Plates low, wide, rugose; primary tubercles somewhat smaller from apical system to slightly above ambitus, no tubercles in median region, one tubercle on each plate near adradial suture. Tubercles largest at ambitus then reducing in size to peristome; usually two tubercles one each plate.

Peristome — Very large, approximately one-half as wide as horizontal diameter of test,

round to sub-pentagonal; gill slits wide, continuing fair distance on test surface.

Tuberculation — Tubercles imperforate, smooth on finely rugose bosses, largest at ambitus. Where absent, plates rugose.

Occurrence — Spoil piles, Yorktown Formation (Lower Pliocene), PCS Phosphate (Lee Creek) Mine, near Aurora, Beaufort County, North Carolina.

Discussion — Cooke (1941; 1959) described several species of *Arbacia* from Late Miocene-Early Pliocene sediments of Virginia and South Carolina including: *A. waccamaw* Cooke, 1941, *A. rivuli* Cooke, 1941, *A. sloani*, and *A. improcera*. Kier (1963) described *A. crenulata* from the Tamiami Formation of Florida and reported *A. improcera* from the Yorktown Formation of Virginia and at the PCS Phosphate (Lee Creek) mine (Kier, 1972; 1983). Specimens described here differ from *A. waccamaw* by lacking a depressed test and by having much lower and wider interambulacral plates. *Arbacia rivuli* differs from specimens referred here in lacking conspicuous bare spaces on the interambulacra and having some insert ocular plates.

Specimens here are most similar in size, shape and ornamentation to *A. crenulata*, *A. improcera*, or *A. sloani*. However, Kier (1972) in his discussion of *A. improcera* suggested all three species may be synonymous. Kier (1972) cited that *A. improcera* might be conspecific with *A. crenulata*, because new material representative of *A. improcera* showed crenulations similar to those of *A. crenulata*. The two may still be separate species, however, as specimens described as *A. crenulata* by Kier (1963) lack tubercles on ocular plates, whereas tubercles are present on *A. improcera*. The specimens described here each possess tubercles on their ocular plates and thus are likely to be either *A. improcera* or *A. sloani*.

Cooke (1941) stated the most notable difference between *A. sloani* and *A. improcera* as greater height in *A. sloani*. Cooke (1959) noted that *A. improcera* is flatter with a more rugose sculpture than *A. sloani*. Kier (1972) observed that, with more specimens differences in heights between *A. improcera* and *A. sloani* were slight: 49 percent versus 53 percent; he

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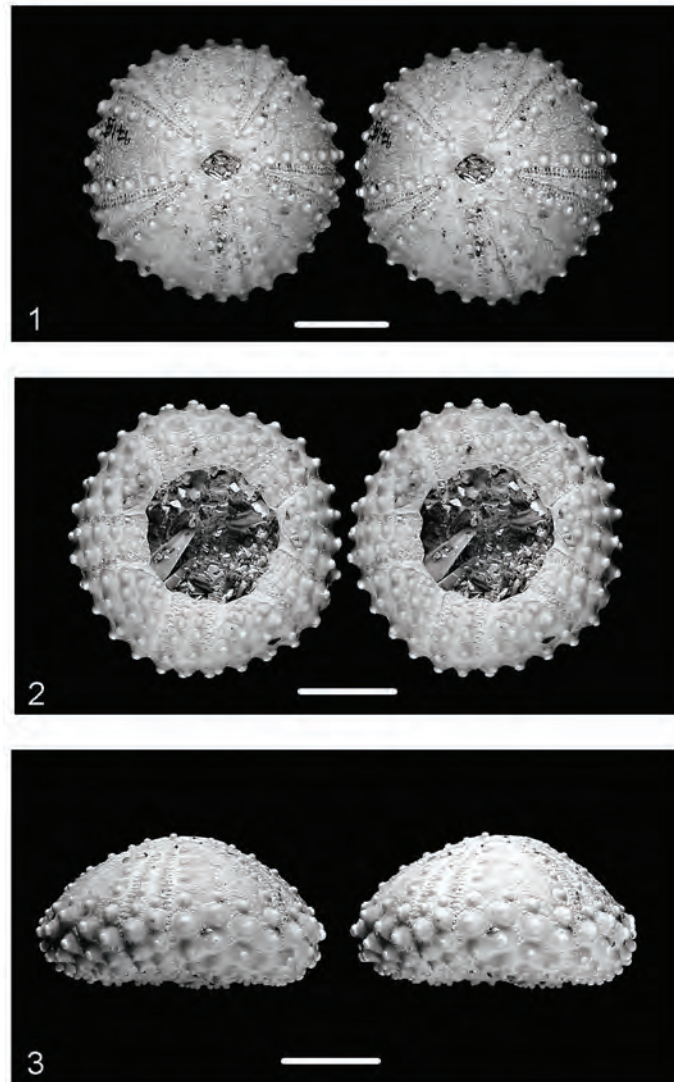


Figure 3: Stereo pairs of NCSM 9715, *Arbacia* sp. cf. *A. sloani* (Clark in Clark and Twitchell, 1915); 3.1 aboral view, 3.2 oral view, 3.3 lateral view. Scale bars = 10 mm.

could see no distinguishing features between the two species. Kier (1972) further suggested that *A. improcera* and *A. sloani* might be synonymous, but felt more specimens were required to resolve the issue. The two specimens we report herein have ornamentation similar to *A. improcera*, but have heights of 54 and 58 percent of their diameter, suggesting that they are most similar to *A. sloani*. Until the issue of synonymy between *A. improcera* and *A. sloani* can be resolved with more specimens these specimens

are considered *Arbacia* sp. cf. *A. sloani*.

ORDER	CLYPEASTEROIDA A. AGASSIZ, 1872
Suborder	SCUTELLINA Haeckel, 1896
Family	MELLITIDAE Stefanini, 1911
Genus	<i>Encope</i> L. Agassiz, 1840
Species	<i>Encope macrophora</i>

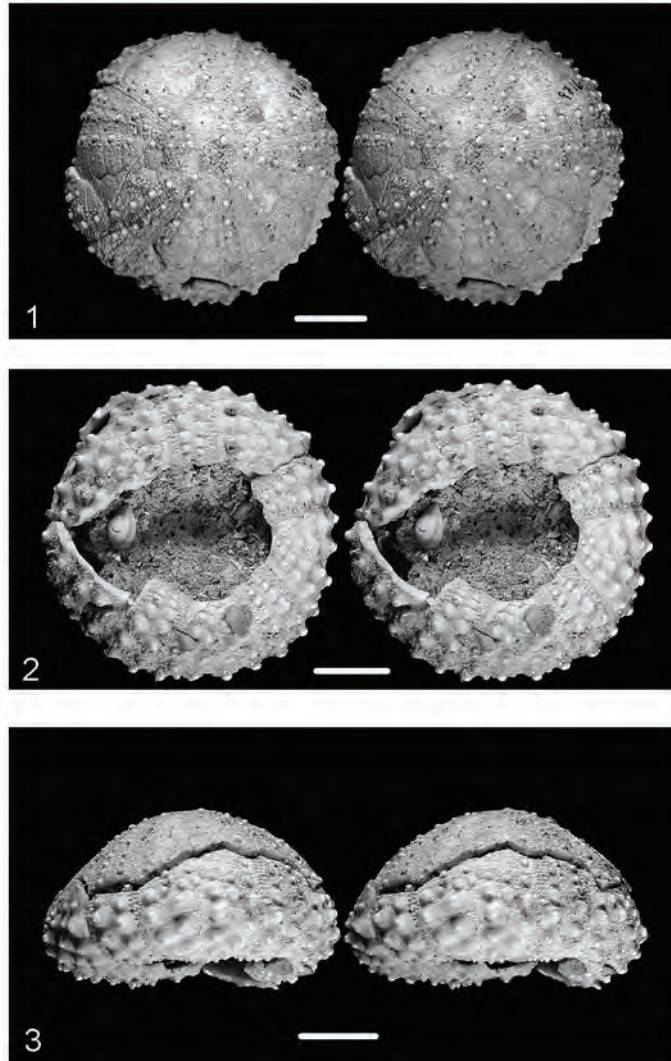


Figure 4: Stereo pairs of NCSM 9716, *Arbacia* sp. cf. *A. sloani*; 4.1 aboral view, 4.2 oral view, 4.3 lateral view. Scale bars = 10 mm.

(RAVENEL, 1842)

Material — One juvenile specimen (NCSM 9717: Figure 5.1 - 5.3)

Measurements — Length 29.1 mm, width 25.6 mm.

Description — Specimen heavily coated with calcite-cemented detritus, few surface details visible. Due to uniqueness and apparent fragility, no attempt beyond simple washing was made to clean the specimen.

Three anterior ambulacral notches not developed; two posterior notches form shallow in-

dentations in edge of test. Interambulacral (anal) lunule large, well-developed. Anal pore (partially damaged) contained in wall of interambulacral lunule nearest peristome. Faint suggestions of feeding grooves. Interambulacral plates, barely visible, just to right of upper center on oral side. Unfortunately, a hole passes through center of test, completely obliterating peristome and aboral ambulacral center. Portions of five ambulacra visible. Fragments of several spines cemented to test, spine on adoral surface near interambulacral lunule resembles

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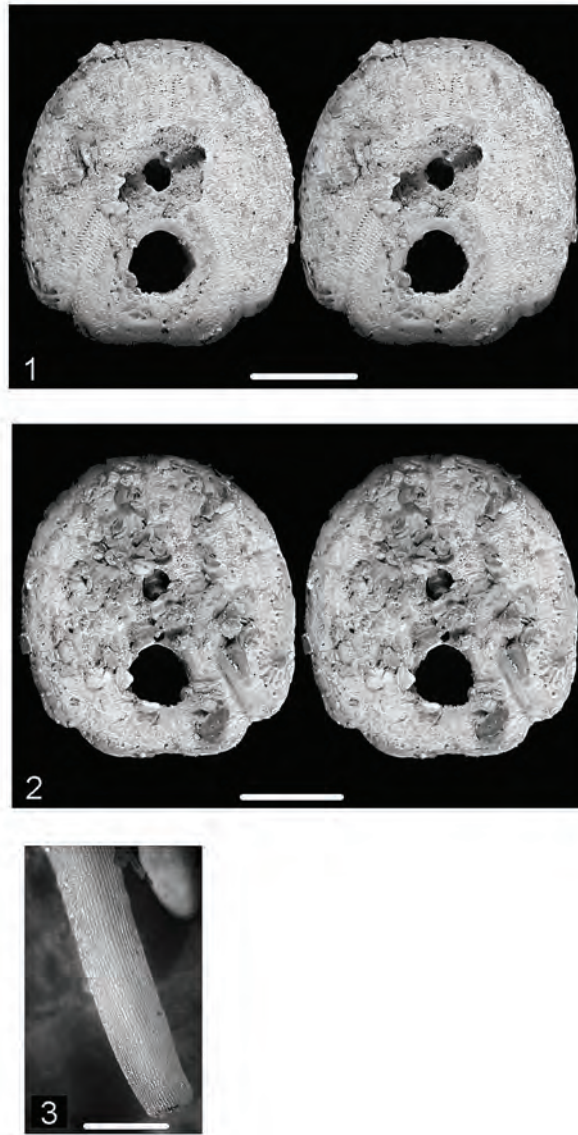


Figure 5: Stereo pairs of NCSM 9717, *Encope macrophora* (Ravenel, 1842); 5.1 aboral view, 5.2 oral view, 5.3 spine. Scale bars = 10 mm, except 1 mm for spine.

spines from extant *Encope* species.

Occurrence — Spoil piles, Yorktown Formation (Lower Pliocene), PCS Phosphate (Lee Creek) Mine, near Aurora, Beaufort County, North Carolina. Collector could not completely rule out that source was nearby James City sediments.

Discussion — Comparison with juvenile specimens of *Encope tamiamiensis* Mansfield, 1932 and *E. macrophora* of almost identical size in-

dicates NCSM 9717 is *E. macrophora*. The primary difference between this specimen and *E. tamiamiensis* is the size of the interambulacral lunule and the complete absence of anterior notches. The height: width ratio of NCSM 9717 is 1.14 while that of the juvenile *E. tamiamiensis* was 1.07, much closer to Cooke's (1959) description of that species: "test as wide as long." The specimen described here also shows curving of the posterior ambulacra around the

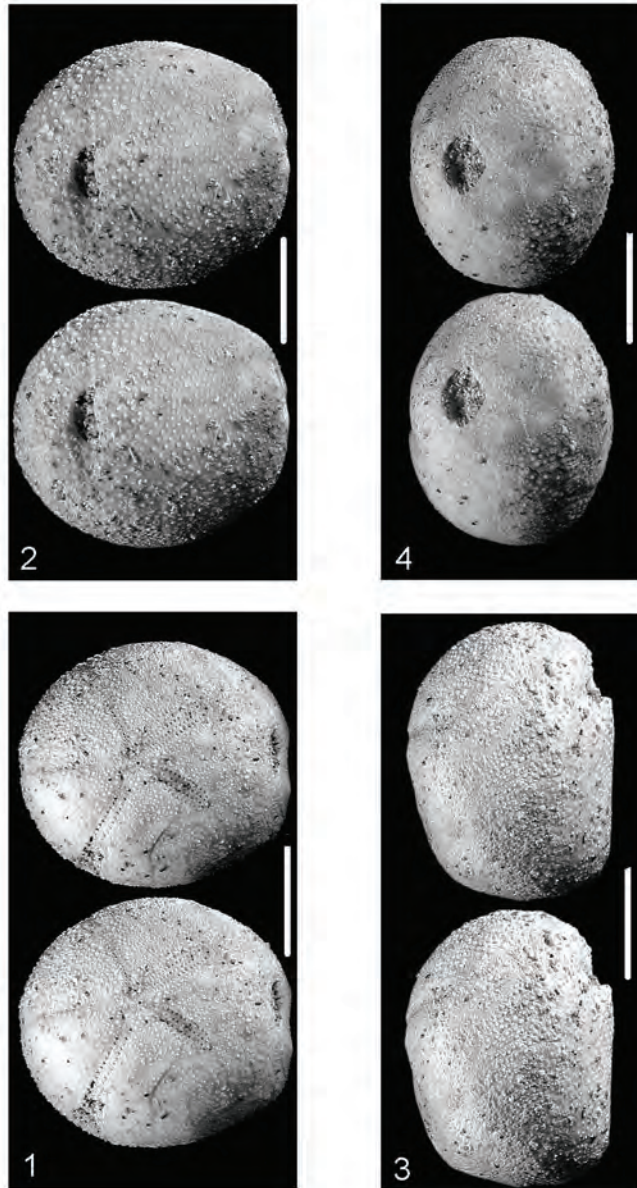


Figure 6: Stereo pairs of NCSM 9718, *Agassizia scrobiculata* Valenciennes, 1846; 6.1 aboral view, 6.2 oral view, 6.3 lateral view, 6.4 periproctal view. Scale bars = 10 mm.

lunule, which is consistent with *Encope macrophora*. In *Encope tamiamiensis* the posterior ambulacra are much more nearly straight.

Order SPATANGOIDA Claus, 1876

Suborder HEMIASTERINA Fischer,
1966

Family SCHIZASTERIDAE Lambert,
1905

Genus *Agassizia* Agassiz and
DESOR, 1847

Species *Agassizia scrobiculata*
VALENCIENNES, 1846

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Material — One complete test (NCSM 9718: Figure 6.1 - 6.4).

Measurements — Height 19.4 mm with greatest height posterior to center. Length 25.0 mm, width 22.7 mm. Width to length ratio is 0.93 with greatest width posterior to center. Height to length ratio is 1.07.

Description:

Test — Small, subglobular, slightly inflated anteriorly with posterior truncation not overhanging and dipping steeply. Horizontal outline ovate, widest in front, anterior portion convex, posterior portion concave below truncation.

Apical disk — Subcentral to slightly posterior (located 47 percent of test length from anterior margin). Detailed structure not visible.

Ambulacra — Ambulacra II and IV not petaloid, extend to margin, slightly sunken with single row of pore pairs. Ambulacra I and V petaloid, extend 60 percent of radius to margin, slightly sunken with a double row of pore pairs. Ambulacra III is subdued, not petaloid, extends to radius and too weathered to discern pores.

Interambulacral plates — Not visible.

Fascioles — Peripetalous fasciole anteriorly low, below margin, passing below petals II and IV, abruptly rising adapically and passing close, posteriorly below petals I and V. Lateroanal fasciole forms posterior to petals II, IV and extends to posterior just below periproct forming V-shaped sulcus. Four plates form sulcus, each with single large “bump.”

Peristome — Large, with pronounced lip, crescent shaped, 3.9 mm long by 2.4 mm wide at maximum, located 21 percent of test length from anterior margin.

Periproct — High on posterior portion of test on truncation, transversely oval.

Plastron — Raised with large tubercles in biradial pattern.

Occurrence — Spoil piles, James City (Upper Pliocene/Pleistocene), PCS Phosphate (Lee Creek) Mine, near Aurora, Beaufort County, North Carolina.

Discussion — Cooke (1959) described *Agassizia scrobiculata* and *Agassizia porifera* (Ravenel, 1848) from Late Miocene and Kier (1963) reported *A. porifera* from the Upper Pliocene Caloosahatchee Formation in Florida. The

specimen described here is clearly most similar to *A. scrobiculata* specimen described in Cooke (1959). This specimen does not have the rear truncation overhanging and is less inflated than *A. porifera*. The *A. porifera* specimens described by Kier (1963) ranged in length from approximately 50 mm to 79 mm and in width from 50 mm to 76 mm respectively. The specimen described here is significantly smaller and features in common with *A. scrobiculata* include overall test shape, petal pattern (including narrow and depressed ambulacra III), double pore spacing of ambulacra II and IV, lack of a deep sulcus and raised peristome with labrum.

ACKNOWLEDGMENTS

We are extremely grateful to North Carolina Fossil Club members Eric Sadorf, Judy Stiles, and Patricia Young for donating specimens to this study and to Janet Edgerton and Mikaela Mroczynski (NCSM) for bibliographic assistance. We are also thankful to James Knight (South Carolina Museum of Natural Sciences) and Jann Thompson (U.S. National Museum) for providing images and specimens for comparison.

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