

American Upper Cretaceous Echinoidea

By C. WYTHE COOKE

A SHORTER CONTRIBUTION TO GENERAL GEOLOGY

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*Descriptions and illustrations of
Upper Cretaceous echinoids from the
Coastal Plain and western interior
of the United States and from Guatemala*



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AMERICAN UPPER CRETACEOUS ECHINOIDEA

By C. WYTHE COOKE

ABSTRACT

Most of the 58 species (in 8 genera) of known Upper Cretaceous echinoids are found in the Gulf series in the States from Texas to North Carolina. Of six species that came from the western interior United States only *Hemiaster humphreysanus* occurs also in the Gulf series. Ten species from New Jersey, Delaware, or Maryland have not been recognized elsewhere. Three species from Guatemala are included.

Descriptions of the genera herein given include references to the type species and mention their characteristic features. One new genus, *Barnumia*, is described. Also included are a dichotomous key to the genera, keys to the species of *Hardouinia* and *Hemiaster*, and a correlation table of echinoid-bearing formations.

The following species are described as new: *Salenia hondoensis*, *Porosoma reesidei*, *Codiopsis stephensoni*, *Rachiosoma hondoensis*, *Lanieria waldana*, *Conulus stephensoni*, *Globator vaughani*, *Faujasia chelonium*, *Catopygus mississippiensis*, *Lefortia trojana*, *Hardouinia mcglameryae*, *Pseudananchys stephensoni*, *Holaster feralis*, *Cardiaster deciper*, *Isomicraster rossi*, *Isomicraster danei*, *Barnumia browni*, *Hemiaster arcolensis*, *Hemiaster sabinal*, *Hemiaster amelianus*, and *Micraster uddeni*.

Transfers of species to a different genus include *Cyphosoma mortoni* De Lorient to *Rachiosoma*; *Pseudodiadema hilli* Clark to *Phymosoma*; *Echinobrissus texanus* Clark to *Nucleopygus*; *Clypeaster geometricus* Morton to *Pygurostoma*; *Echinobrissus cubensis* Weisbord to *Phyllobrissus*; *Cassidulus hemisphericus* Slocum to *Clarkiella*; and *Cassidulus emmonsii* Stephenson, *Cassidulus keltumi* Stephenson, *Cassidulus micrococcus* Gabb, *Cassidulus aequoreus* Morton, *Clypeaster florealis* Morton, *Cassidulus stantoni* Clark, and *Cassidulus taylora* Warren to *Hardouinia*.

INTRODUCTION

This report is based chiefly on collections in the United States National Museum. Besides these, which include most of the material studied by William Bullock Clark (1891, 1893, 1915) and Lloyd W. Stephenson (1927, 1941), some specimens, including types, were loaned by the Academy of Natural Sciences of Philadelphia, the New Jersey State Museum at Trenton, the

Alabama Museum of Natural History at Tuscaloosa, the Paleontological Research Laboratories at Statesville, North Carolina, and the University of Alberta at Edmonton. For this additional material I am indebted to Dr. Horace G. Richards, Miss Winnie McGlamery, Dr. Richard L. Casanova, and Prof. P. S. Warren.

Especial thanks are due to L. W. Stephenson, John B. Reeside, Jr., and William A. Cobban, all of the United States Geological Survey, who contributed important data on the stratigraphic ranges of several species.

The scope of this report is less inclusive than might be inferred from the title, which was selected for brevity. The word American as used here applies primarily to the United States, though a few of the species described occur also in Mexico, Brazil, Guatemala, or in Canada. Only the post-Cenomanian Upper Cretaceous echinoids are described. This excludes the species from the Upper Cretaceous Buda limestone of Texas, which, though of early Cenomanian age, is classified as part of the Comanche series, most of which is of early Cretaceous age. The echinoid fauna of the Buda has been described by Whitney (1916), and its species were included in my paper on the Comanche echinoids (Cooke, 1946).

Also excluded from the report are the Cretaceous echinoids of the Pacific coastal States. These were described by Kew (1920), who lists the following Cretaceous species: *Cidarites tehamaensis* Clark, *Catopygus californicus* Kew, *Hemiaster cholamensis* Kew, *Hemiaster californicus* Clark, *Hemiaster alamedensis* Kew, *Hemiaster oregonensis* Kew, and *Epiaster depressus* Kew.

The greater number of species described herein were derived from the Gulf series in the states from Texas to North Carolina. Also all the known species from the western interior are included. These are *Porosoma reesidei* Cooke, n. sp.; *Hardouinia stantoni* (Clark); *Hardouinia taylora* (Warren); *Hemiaster beecheri* Clark; *Hemiaster humphreysanus* Meek and Hayden; *Cardiaster curtus* Clark; and *Holaster feralis* Cooke, n. sp. The type of *Scutellaster cretaceus* Cragin, found at Colorado Springs, Colorado, and heretofore supposed to be Cretaceous, is probably a curio from the west

Coast discarded by some tourist. It is certainly not Cretaceous. It has been identified by J. Wyatt Durham (1953, pp. 147-148) as the common Pliocene species *Anorthoscutum interlineatum* (Stimpson).

Eight species from New Jersey and Delaware are represented for the most part by casts of the interior. They are *Pygurostoma geometricum* (Morton), *Catopygus pusillus* Clark, *Catopygus (Oolopygus) williamsi* Clark, *Hardouinia florealis* (Morton), "*Hemiaster*" *kummeli* Clark, *Hemiaster welleri* Clark, *Hemiaster delawarensis* Clark, and *Cardiaster smocki* Clark. These species have not been recognized elsewhere, and the state of preservation of most of them is such as to make recognition uncertain. One species, *Cardiaster marylandicus* Clark, comes from the Monmouth formation of Maryland.

The stratigraphic location of most of the geologic formations from which the American Upper Cretaceous echinoids have been derived is indicated in the correlation table, Figure 1, in which the formations are referred

to the standard Upper Cretaceous time scale of Europe. Only the echinoid-bearing formations are listed in that table. For the complete sequence in the Coastal Plain the reader is referred to tables by Stephenson, King, Monroe, and Imlay (1942) and by Monroe (1946); for the western interior of the United States to tables by Cobban and Reeside (1952). The division of the Maestrichtian into three parts is arbitrary. It signifies merely relative position.

The distribution of species according to their geologic horizon is shown in the accompanying table. It will be noted that the geologic range of most species is limited to one stage. For that reason, most echinoids are excellent horizon markers.

The initials U.S.G.S. followed by a serial number indicates an entry in the register of Mesozoic localities of the Paleontology and Stratigraphy Branch of the United States Geological Survey. The initials U.S.N.M. stand for the United States National Museum.

				TEXAS	ARKANSAS	MISSISSIPPI, ALABAMA	NORTH CAROLINA, SOUTH CAROLINA	NEW JERSEY
Senonian	Maestrichtian	Late	Navarro group	Escondido formation Kemp clay Corsicana marl		Providence sand Prairie Bluff chalk		
		Early		Nacatoch sand		Ripley formation	Peedee formation	Navesink marl
		Early		Neylandville marl	Saratoga chalk			Mount Laurel sand
	Campanian	Anacacho limestone and Taylor marl	Annona chalk	Marshalltown formation				
	Santonian	Austin chalk		Arcola sandstone member of the Mooreville chalk	Woodbury clay			
	Coniacian			— ? —	Merchantville clay			
			Tombigbee sand member of the Eutaw formation					
	Turonian	Eagle Ford shale						
	Cenomanian	Buda limestone						

FIGURE 1.—Stratigraphic location of some echinoid-bearing formations of the Coastal Plain.

Stratigraphic range of American Upper Cretaceous echinoids

	Turo- nian	Coni- acian	San- tonian	Campa- nian	Maestrichtian		
					Lower	Middle	Upper
<i>Cidaris wahalakensis</i> De Loriol							×
<i>C. texanus</i> Clark				×			
<i>Salenia hondoensis</i> Cooke, n. sp.				×			
<i>Porosoma reesidei</i> Cooke, n. sp.		×					
<i>Pedinopsis pondi</i> Clark		?	?				
<i>Codiopsis stephensoni</i> Cooke, n. sp.							×
<i>Rachiosoma hondoensis</i> Cooke, n. sp.							×
<i>R. mortoni</i> (De Loriol)						×	
<i>Phymosoma hilli</i> (Clark)							
<i>Lanieria uwaldana</i> Cooke, n. sp.				×			
<i>Conulus stephensoni</i> Cooke, n. sp.			×				
<i>Globator vauhani</i> Cooke, n. sp.				×			
<i>Nucleopygus texanus</i> (Clark)		×					
<i>Pygurostoma geometricum</i> (Morton)				×			
<i>P. passionensis</i> Cooke				?			
<i>Faujasia chelonium</i> Cooke, n. sp.							×
<i>Catopygus pusillus</i> Clark			×				
<i>C. mississippiensis</i> Cooke, n. sp.							×
<i>C. (Oolopygus) williamsi</i> Clark						×	
<i>Lefortia trojana</i> Cooke, n. sp.						×	
<i>Phyllobrissus cubensis</i> (Weisbord)			×	×			
<i>Clarkiella hemispherica</i> (Slocum)							×
<i>Hardouinia mortoni</i> (Michelin)						×	×
<i>H. mortoni emmonsii</i> (Stephenson)						×	×
<i>H. kellumi</i> (Stephenson)						×	×
<i>H. micrococcus</i> (Gabb)						×	×
<i>H. bassleri</i> (Twitchell)			×				
<i>H. aequorea</i> (Morton)							×
<i>H. florealis</i> (Morton)				?			
<i>H. stantoni</i> (Clark)	×						
<i>H. taylori</i> (Warren)				×			
<i>H. mcglameryae</i> Cooke, n. sp.							?
<i>Echinocorys texanus</i> (Cragin)				×			
<i>Pseudananchys stephensoni</i> Cooke, n. sp.			?				
<i>Holaster feralis</i> Cooke, n. sp.	×						
<i>Cardiaster deciper</i> Cooke, n. sp.					×		
<i>C. leonensis</i> Stephenson				×			×
<i>C. curtus</i> Clark				×			
<i>C. smocki</i> Clark			×				
<i>C. marylandicus</i> Clark							×
<i>Isomicraster rossi</i> Cooke, n. sp.	×						
<i>I. danei</i> Cooke, n. sp.			×	?			
<i>Barnumia browni</i> Cooke, n. sp.							
<i>Hemiaster humphreysanus</i> Meek and Hayden						×	
<i>H. beecheri</i> Clark				×			
<i>H. wetherbyi</i> De Loriol					×	×	×
<i>H. arcolensis</i> Cooke, n. sp.			×				
<i>H. jacksoni</i> Maury	×						
<i>H. texanus</i> Roemer			×	×			
<i>H. sabinal</i> Cooke, n. sp.		?	?				
<i>H. ungula</i> Morton				?			
<i>H. kummeli</i> Clark				×			
<i>H. delawarensis</i> Clark					?		
<i>H. welleri</i> Clark			×				
<i>H. amelianus</i> Cooke, n. sp.				?			
<i>Linthia variabilis</i> Slocum						×	×
<i>Proraster dalli</i> (Clark)				×			×
<i>Micraster uddeni</i> Cooke, n. sp.			×				
<i>M. americanus</i> Stephenson					×	×	×

KEY TO THE GENERA OF AMERICAN UPPER CRETACEOUS ECHINOIDS

Symmetry dominantly radial; peristome generally central	
Periproct within the apical system	
Ambulacra narrow throughout	
Tubercles perforate; apical system without suranal plates.....	<i>Cidaris</i>
Tubercles imperforate; central suranal plate present.....	<i>Salenia</i>
Ambulacra widening to the ambitus	
Tubercles perforate	
Poriferous zones uniserial.....	<i>Porosoma</i>
Poriferous zones biserial above the ambitus.....	<i>Pedinopsis</i>
Tubercles imperforate	
Primary tubercles only on oral surface	
Primary tubercles in a star-shaped cluster.....	<i>Codiopsis</i>
Primary tubercles not in a star-shaped cluster.....	<i>Boletechinus</i> ¹
Primary tubercles not only on oral surface	
Poriferous zones generally uniserial throughout.....	<i>Rachiosoma</i>
Poriferous zones plainly biserial above the ambitus.....	<i>Phymosoma</i>
Periproct outside the apical system	
Peristome without floscelle; ambulacra continuous or subpetaloid; periproct pyriform	
Five genital plates; globular.....	<i>Lanieria</i>
Four genital plates	
Poriferous zones continuous; peristome oblique, flush	
Periproct terminal, erect.....	<i>Globator</i>
Periproct submarginal, inclined.....	<i>Conulus</i>
Poriferous zones subpetaliferous; peristome sunken; periproct supra-marginal, opening into a depression.....	<i>Nucleopygus</i>
Peristome with floscelle; ambulacra petaloid, petals flush or swollen; periproct not pyriform	
Periproct marginal or inframarginal	
Periproct marginal, erect, elongate.....	<i>Lefortia</i>
Periproct inframarginal, rostrate, turned down obliquely	
Periproct transverse.....	<i>Faujasia</i>
Periproct elongate.....	<i>Pygurostoma</i>
Periproct supramarginal	
Posterior end truncate; periproct terminal.....	<i>Catopygus</i>
Posterior end not truncate	
Periproct flush; peristome anteriorly eccentric.....	<i>Clarkiella</i>
Periproct opening into a sulcus	
Phyllodes high, pointed; peristome central.....	<i>Hardouinia</i>
Phyllodes low, rounded; peristome anteriorly eccentric.....	<i>Phyllobrissus</i>

¹ New genus. Type species *Boletechinus meglameryae* Cooke manuscript. An undescribed genus discovered too late to be included in this report.

Symmetry plainly bilateral; peristome generally far forward	
Apical system elongated; paired ambulacra subpetaloid, flush	
Anterior poriferous zones like the others; not sulcate in front	
Pores circular or oval; periproct submarginal.....	<i>Echinocorys</i>
Outer pores elongated; periproct supra-marginal.....	<i>Pseudananchys</i>
Anterior poriferous zones unlike the others; sulcate in front	
No fascioles.....	<i>Holaster</i>
Marginal fasciole.....	<i>Cardiaster</i>
Apical system not elongated; paired ambulacra petaloid	
Anterior petal like the paired petals	
Petals sunken; peristome lipped; lower surface flattish; no complete fascioles.....	<i>Isomicraster</i>
Petals flush; peristome not lipped; lower surface convex; marginal fasciole.....	<i>Barnumia</i>
Anterior petal unlike the paired petals; petals sunken	
Subanal fasciole; no peripetalous fasciole.....	<i>Micraster</i>
No subanal fasciole; peripetalous fasciole	
Lateral fascioles.....	<i>Linthia</i>
No lateral fascioles	
Anterior petals straight.....	<i>Hemiaster</i>
Anterior petals flexuous.....	<i>Proraster</i>

SYSTEMATIC DESCRIPTIONS

Genus CIDARIS Leske

- Cidaris* Leske, 1778, Klein's *Naturalis dispositio Echinodermatum*, p. XVII.
Cidarites (part) Lamarck, 1816, *Histoire naturelle des animaux sans vertèbres*, tome 3, p. 52.
Cidaris Leske. A. Agassiz, 1872, Harvard College, Mus. Comp. Zoology, Mem., vol. 3, p. 252.
Cidaris (*Eucidaris*) Pomel, 1883, *Classification méthodique et genera des échinides*, p. 109.
Cidaris Leske. H. L. Clark, 1907, Harvard College, Mus. Comp. Zoology, Bull., vol. 51, p. 183.
Cidaris Leske. Mortensen, 1928, *Monograph of the Echinoidea*, vol. 1, p. 286.
Cidaris Leske. Cooke, 1941, *Jour. Paleontology*, vol. 15, no. 1, p. 5.
Cidaris Leske. Cooke, 1946, *Jour. Paleontology*, vol. 20, no. 3, p. 199.

Type species, *Cidaris papillata* Leske (1778, p. 125) = *Echinus cidaris* Linneus (1758, *Systema naturae*, edition 10, p. 664), by tautonymy. This species is identified by Mortensen (1928, p. 289) as the common species inhabiting the eastern part of the Atlantic Ocean. This designation may as well be accepted, though Linnaeus' original references include several to a Pacific species.

Cidaris cidaris as figured by Mortensen (1928, pl. 30, figs. 3, 4; pl. 31, figs. 1-10; pl. 67, fig. 5; pl. 72, figs.

20-22) is fairly large, oblate spheroidal, with slightly sinuous, narrow ambulacra, which do not vary much in width. Its apical system, which is nearly circular, is somewhat larger than its peristome, which is pentagonal and without notches. It has two rows of plates in each ambulacrum and interambulacrum, and about six or seven tiers of coronal plates in each interambulacral row. Its ambulacral pores are conjugate, and each zygopore is slightly tilted. Its primary spines are long, slender, and decorated with longitudinal serrate ridges. According to Mortensen (1928, p. 296) it has both large and small globiferous pedicellariae as well as tridentate.

Mortensen (1928, p. 50) regards the pedicellariae as having "very high classificatory value, partly of specific, partly of generic and of sub-family value". He appears to have attributed more importance to them than they deserve, because his classification based on them puts in different genera species that otherwise seem very similar. Many of his generic names will doubtless fall into the synonymy of *Cidaris*. No attempt at rectification is made here.

Cidaris wahalakensis De Loriol

Plate 1, figures 1, 2

Cidaris nahalakensis De Loriol, 1887, Recueil zool. Suisse, vol. 4, p. 388, pl. 17, figs. 3, 3a, 4-4b. (Error of transcription for *wahalakensis*.)

Cidaris nahalakensis De Loriol. Clark, 1893, U. S. Geol. Survey Bull. 97, p. 93.

Cidaris nahalakensis De Loriol. Clark, 1915, U. S. Geol. Survey Mon. 54, p. 48.

Spines long and slender; shaft decorated with about 9 longitudinal rows of nearly confluent granules, intermediate areas very finely striated; neck very finely striated, merging into the shaft.

Occurrence.—Mississippi: Wahalak, Kemper County (type).

Alabama: U.S.G.S. 18143, NW $\frac{1}{4}$, SW $\frac{1}{4}$, T 19 N, R 2 W, Sumter County (U.S.G.S. 18142, W. H. Monroe).

Geologic horizon.—Prairie Bluff chalk.

Remarks.—This species, known only from spines, has been identified with considerable assurance because the specimens from Alabama here figured (U.S.N.M. 108365) not only resemble De Loriol's figures but are supposed to have occupied the same stratigraphic horizon. They were collected not very far from the type locality, which is in the adjoining county in Mississippi.

Cidaris texanus Clark

Plate 1, figure 14

Cidaris texanus Clark, 1891, Johns Hopkins Univ. Circ., vol. 10, no. 87, p. 75.

Cidaris texanus Clark. Clark, 1893, Johns Hopkins Univ. Circ., vol. 12, no. 103, p. 61.

Cidaris texanus Clark. Clark, 1893, U. S. Geol. Survey Bull. 97, p. 36, pl. 7, figs. 1a-e.

?*Cidaris dixiensis* Cragin, 1893, Texas Geol. Survey Ann. Rept. 4, pt. 9, p. 146, figs. 15, 16.

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Cidaris texanus Clark. Clark, 1915, U. S. Geol. Survey Mon. 54, p. 45, pl. 9, figs. 2a-f.

?*Cidaris dixiensis* Cragin. Clark, 1915, U. S. Geol. Survey Mon. 54, p. 45, pl. 9, figs. 7a-b.

Dorocidaris texanus (Clark). Lambert, 1926, Soc. géol. France Bull., tome 26, p. 265.

Dorocidaris texanus (Clark). Adkins, 1928, Texas Univ. Bull., no. 2838, p. 271.

?*Cidaris dixiensis* Cragin. Adkins, 1928, Texas Univ. Bull., no. 2838, p. 271.

Test large. Apical scar proportionately small. Ambulacra narrow, slightly undulating; pores oval, separated by a granule; zygopores slightly inclined. Interambulacra having probably about seven plates in each tier; sutures conspicuous. Primary tubercles smooth, perforated, widely separated; miliary granules tall.

Occurrence.—Texas: Bexar County (type); Hill's no. 354, northwest corner of Cline Mountain, near Cline, Uvalde County, R. T. Hill, (upper layer of Austin chalk); U.S.G.S. 7708, "Chalk Bluff" on Sabinal Creek, right bank, 2.5 to 3 miles north of Sabinal, Uvalde County, L. W. Stephenson, (Anacacho limestone); U.S.G.S. 18587, 150 feet south of new highway 85 at east bank of Tequesquite Creek, Maverick County, R. R. Bennett, (upper part of Austin chalk).

Geologic horizon.—The original catalogue entry attributes the type (then labeled *Hemicidaris* sp.) to the Cretaceous. W. B. Clark thought it came from the Washita group (Lower Cretaceous). Nothing like it has been found in the Washita, but several specimens that apparently represent this species came from the Austin chalk and the Anacacho limestone. *Cidaris dixiensis*, known only from unidentifiable plates, is attributed to the Taylor marl.

Type.—U.S.N.M. 8381.

Remarks.—*Cidaris texanus* was tentatively placed in the synonymy of *Cidaris hemigranulosus* Shumard in my paper on the Comanche echinoids (Cooke, 1946, p. 199), but the receipt of better-preserved specimens of that species shows that the two represent different subgenera. *Cidaris hemigranulosus* apparently belongs to the subgenus *Stereocidaris* Pomel (1883, p. 110), type species *Cidaris cretosa* Mantell, whereas *C. texanus* seems to be a typical *Cidaris*.

Genus *SALENIA* Gray

Salenia Gray, 1835, Zool. Soc. London Proc., vol. 3, p. 58.

Salenia Gray. Mortensen, 1935, Monograph of the Echinoidea, vol. 2, p. 367. Gives additional synonymy.

Salenia Gray. Cooke, 1941, Jour. Paleontology, vol. 15, no. 1, p. 7.

Salenia Gray. Cooke, 1946, Jour. Paleontology, vol. 20, no. 3, p. 202.

Type species *Cidarites scutiger* Münster (in Goldfuss, 1826, pl. 49, figs. 4a-b), by monotypy, from the Cenomanian of Germany. The known range of the genus is from Lower Cretaceous to Recent. It is most abundant in the Upper Cretaceous.

Specific distinctions between the *Salenias* are based mainly on the shape and ornamentation of the apical disc. This ranges in shape from circular, as in the type species, to pentagonal. There is much variation in the

shape of the individual apical plates. In some species they are consistently though variably lobed; in others they are straight-sided. The sutures between the apical plates may be open, grooved, or fused. Many species have circular or slot-shaped perforations along the sutures.

Besides the five ocular and five genital plates, the salenids have a central suranal plate, which displaces the periproct from its normal central location. In *Salenia* the periproct lies to the right and behind the center, contrasting with *Hyposalenia* Desor 1856 (*Peltastes* Agassiz 1838, not Illiger 1807) and *Goniophorus* Agassiz 1838, in both of which the periproct lies directly behind the suranal plate.

Salenia hondoensis Cooke, n. sp.

Plate 1, figures 3, 4

Test moderately inflated. Apical system raised, smooth, plainly pentagonal, nearly straight-sided, sides indented at the suture lines; ocular plates sagittate; genital plates dumbbell-shaped, being constricted laterally by the ocular plates, having the genital pores near the center, madreporite rather large, confined to the right anterior plate; central plate straight-sided except where truncated by the periproct, protruding at the periproct; sutures fused, with circular perforations at the corners and midway between them. Ambulacral areas narrow, widening toward the peristome, containing two rows of small imperforate tubercles separated by granules; poriferous zones straight, uniserial. Interambulacral areas much wider, with two rows of about 5 large primary, imperforate, crenulate tubercles, each primary tubercle ringed by small tubercles, and the intermediate areas granulated. Peristome large, circular, strongly notched. Periproct excentrically within the apical system, adjoining the central plate and the posterior and right-posterior genital plates.

Horizontal diameter 18.7 mm; height 11.6 mm; diameter of apical system 11.7 mm; diameter of peristome 8.2 mm.

Occurrence.—Texas: King's Water Hole, 3 miles north of Hondo, Medina County (U.S.G.S. 12902, L. W. Stephenson).

Geologic horizon.—Anacacho limestone.

Type.—U.S.N.M. 108366.

Comparisons.—This species, which is represented by only one specimen, is rather like *Salenia seigipensis* White (1887, p. 252, pl. 27, figs. 11, 12) from the Cretaceous of Brazil, but its apical system is larger, more sharply pentagonal, and apparently with less distinct sutures. The smoothness, simplicity of ornamentation, and the shape of the apical plates distinguish *Salenia hondoensis* from other Upper Cretaceous species.

Genus POROSOMA Cotteau

Coptosoma Desor, 1855, Synopsis des échinides fossiles, fasc. 2, p. 91. Not Laporte, 1833.

Porosoma Cotteau, 1856, Soc. géol. France Bull., ser. 2, tome 13, p. 648.

Phymosoma (*Coptosoma*) Desor. Pomel, 1883, Classification méthodique et genera des échinides, p. 91.

Coptosoma Desor. Duncan, 1889, Linnean Soc. London Jour., Zoology, vol. 23, p. 87.

Coptosoma Desor. Cotteau, Paléontologie française, Terrain tertiaire, ser. 1, tome 2, p. 486.

Coptosoma Desor. Lambert and Thiéry, 1910, Nomenclature raisonnée des échinides, fasc. 3, p. 219.

Porosoma Cotteau. Lambert and Thiéry, 1914, Nomenclature raisonnée des échinides, fasc. 4, p. 274; 1925, fasc. 8, p. 568.

Porosoma Cotteau. Lambert, 1927, Mus. Ciencias Naturales de Barcelona, Mem., serie geológica, vol. 1, no. 1, p. 64.

Porosoma Cotteau. Mortensen, 1935, Monograph of the Echinoidea, vol. 2, p. 473.

Type species *Cyphosoma cribrum* Agassiz, an Eocene species, designated by Lambert, 1927. As figured by Desor (1855, p. 91, pl. 15, figs. 8–10) this species is characterized by uniserial, polyporous poriferous zones, the zygopores arranged in connected arcs, about seven to each compound plate, not multiplied around the peristome; two rows of large primary, weakly crenate tubercles in each area, the areolas incised by the sutures between the partial plates and surrounded by a circle of coarse granules. Its apical system seems to be circular and rather small; its peristome much larger, about half the total diameter.

Porosoma reesidei Cooke, n. sp.

Plate 1, figures 5–8

Test inflated, margin rounded, slightly concave around the peristome. Apical system not preserved, scar small, pentagonal. Ambulacra more than half as wide as interambulacra; poriferous zones uniserial, sinuous, forming connected arcs around the tubercles, about six pore-pairs to each compound plate, sutures between each platelet conspicuous and indenting the areole. Tubercles imperforate, crenate, forming two rows in each area and a short row on the outer edges of the interambulacra in the peripheral region. Miliary spaces filled with coarse granules. Peristome rather small, one-third as wide as the total diameter. Spines long, thick, cylindrical, very faintly striated, with a thick collar.

Diameter 39 mm; height 18 mm; diameter of apical system about 10 mm; diameter of peristome 14 mm.

Occurrence.—Wyoming: NE 1/4 NW 1/4 sec. 1, T. 42 N., R. 107 W., Fremont County (U.S.G.S. 19537, 23423, R. M. Thompson).

Geologic horizon.—Top of Frontier formation, of Coniacian age.

Types.—Holotype U.S.N.M. 108367; paratype U.S.N.M. 108368.

Remarks.—This species is represented by the type and one paratype. It agrees well with the generic features of *Porosoma cribrum* but has a much smaller peristome. Its apical system, though not preserved, evidently is much smaller than that of

Rachiosoma hondoensis, which also differs in the greater complexity of its poriferous zones.

Genus PEDINOPSIS Cotteau

- Pedinopsis* Cotteau, 1863, Congrès sci. France Mém., session 28, tome 3, p. 176.
- Pedinopsis* Cotteau. Cotteau, 1864, Paléontologie française, Terrain crétacé, ser. 1, tome 7, p. 527; 1867, idem, p. 826.
- Pedinopsis* Cotteau. Wright, 1868, British fossil Echinodermata from the Cretaceous formations, p. 113.
- Pedinopsis* Cotteau. Pomel, 1883, Classification méthodique et genera des échinides, p. 103.
- Pedinopsis* Cotteau. Duncan, 1889, Linnean Soc. London Jour., Zoology, vol. 23, p. 68.
- Dumblea* Cragin, 1893, Texas Geol. Survey Ann. Rept. 4, pt. 2, p. 149.
- Pedinopsis* Cotteau. Lambert and Thiéry, 1910, Nomenclature raisonnée des échinides, fasc. 3, p. 190.
- Dumblea* Cragin. Lambert and Thiéry, 1910, Nomenclature raisonnée des échinides, fasc. 3, p. 207; 1925, idem, fasc. 8, p. 566.
- Pedinopsis* Cotteau. Mortensen, 1935, Monograph of the Echinoidea, vol. 2, p. 451.
- Dumblea* Cragin. Mortensen, 1940, Monograph of the Echinoidea, vol. 3, pt. 1, p. 134.
- Pedinopsis* Cotteau. Cooke, 1946, Jour. Paleontology, vol. 20, no. 3, p. 211.

Type species *Pedinopsis meridanensis* Cotteau (1863, p. 177; 1864, p. 528, pls. 1125, 1126), by monotypy. This Lower Cretaceous (Neocomian) species is distinguished by its biserial poriferous zones and its horizontal rows of small perforated, crenate tubercles.

Mortensen (1940, p. 134) maintains *Dumblea* as a separate genus in a different family (Pedinidae) from *Pedinopsis* (Pseudodiadematidae) because *Dumblea* was reported to have smooth tubercles rather than crenate. This distinction seems invalid because tubercles of some echinoids show all gradations from smooth to plainly crenate. Moreover, the tubercles of *Dumblea symmetrica* Cragin appear to be definitely crenate, though the tubercles are small and the crenulations very minute.

Pedinopsis pondi Clark

Plate 2, figures 1-5

- Pedinopsis pondi* Clark, 1893, Johns Hopkins Univ. Circ., vol. 12, no. 103, p. 51 (nomen nudum).
- Pedinopsis pondi* Clark. Clark, 1893, U. S. Geol. Survey Bull. 97, p. 57, pl. 21, figs. 1a-b; pl. 22, figs. 1a-c.
- Pedinopsis pondi* Clark. Clark, 1915, U. S. Geol. Survey Mon. 54, p. 65, pl. 24, figs. 1a-d.

Test large, highly inflated, margin broadly rounded, flattened on the lower surface, horizontal outline nearly circular. Apical system unknown; not very large. Ambulacra narrow; six pairs of pores to each compound plate above the ambitus, four below it; poriferous zones plainly biserial above the ambitus, series compressed and overlapping below the ambitus and showing a

tendency to arrangement in diagonal groups of four pairs; biserial near the peristome and pores slightly multiplied at it. Coronal plates short and very wide. Tubercles small, perforate, crenate; inconspicuous or eroded on upper part; arranged in even, horizontal rows on and below ambitus, as many as ten on each interambulacral plate at ambitus and four on each ambulacral plate. Peristome small, nearly circular, weakly notched.

Horizontal diameter 88 mm; height 58 mm; diameter of peristome 23 mm; diameter of apical system not more than 11 mm.

Occurrence.—Texas: South bank of Onion Creek about one-fourth mile southwest of the crossing of the Austin and San Antonio wagon road, Travis County. (*Fide* Clark; the label states only Travis County.)

Geologic horizon.—Austin chalk.

Type.—U.S.N.M. 103707 (Johns Hopkins Univ. T 3008).

Remarks.—This large, handsome species is known only from the type.

Genus CODIOPSIS Agassiz

- Codiopsis* Agassiz, 1838, Mon. d'échinodermes, livr. 1, p. 4. Name only.
- Codiopsis* Agassiz, 1840, Catalogus systematicus ectyporum Echinodermatum, pp. 13, 19.
- Codiopsis* Agassiz. Agassiz and Desor, 1847, Catalogue raisonnée des échinodermes, p. 53.
- Codiopsis* Agassiz. Desor, 1858, Synopsis des échinides fossiles, p. 112.
- Codiopsis* Agassiz. Cotteau, 1866, Paléontologie française, Terrain crétacé, tome 7, p. 744.
- Codiopsis* Agassiz. Cotteau and Triger, 1869, Échinides du Département de la Sarthe, p. 404.
- Codiopsis* Agassiz. De Loriol, 1873, Échinologie helvétique, pt. 2, p. 150.
- Codiopsis* Agassiz. Cotteau, 1883, Paléontologie française, Terrain jurassique, tome 10, p. 571.
- Codiopsis* Agassiz. Pomel, 1883, Classification méthodique et genera des échinides, p. 82.
- Codiopsis* (*Hemicodiopsis*) Pomel, 1883, idem, p. 82.
- Codiopsis* (*Piliscus*) Pomel, 1883, idem, p. 82.
- Codiopsis* Agassiz. Duncan, 1891, Linnean Soc. London Jour., Zoology, vol. 23, p. 65.
- Codiopsis* Agassiz. Lambert and Thiéry, 1914, Nomenclature raisonnée des échinides, fasc. 4, p. 263.
- Codiopsis* Agassiz. Sanchez Roig, 1926, Cuba, Bol. Minas, no. 10, p. 41.
- Codiopsis* Agassiz. Mortensen, 1935, Monograph of the Echinoidea, vol. 2, p. 602.
- Codiopsis* Agassiz. Cooke, 1946, Jour. Paleontology, vol. 20, no. 3, p. 215.

Type species *Echinus doma* Desmarest, from the Cenomanian of France, Belgium, and Germany, by monotypy. This species has been figured by Desor (1858, pl. 19, figs. 15-17), Cotteau (1866, p. 781, pls. 1191, 1192), Cotteau and Triger (1869, p. 162, pl. 29, figs. 1-8), Mortensen (1935, p. 603, fig. 356, after Cotteau, 1866), and by Smiser (1935, p. 34, pl. 2, figs. 9a-c). Smiser's photographs show it to be glob-

ular, subpentangular, with narrow ambulacra widening near the peristome as in *Arbacia*, with rows of imperforate tubercles radiating from the peristome but confined to the base. The apical system is dicyclic, with large ocular plates and five perforated genital plates. The periproct is central.

Codiopsis stephensoni Cooke, n. sp.

Plate 1, figures 9–11

Test semiglobose, with flattened base; horizontal outline subpentagonal. Apical system dicyclic, pentagonal, with a large genital pore near each point; ocular plates having one large central tubercle; periproct central. Ambulacra narrow, widening near the peristome; poriferous zones trigeminate, uniserial to the ambitus, zygopores multiplied around the peristome; decorated with two parallel rows of large, imperforate tubercles, which extend from the peristome to the ambitus, above which they are succeeded by very small tubercles, about two to each plate, set in large shallow areoles. Interambulacra very wide, narrowing below the ambitus, decorated below the ambitus with a V-shaped marginal row of large, imperforate tubercles; median part above the ambitus rugose, bare of tubercles, remainder covered with very small tubercles in large, shallow areoles. Peristome subpentagonal, large, half as wide as the horizontal diameter; notches shallow, close together, with callous extensions on the test, separated by a narrow prong.

Horizontal diameter 37.4 mm; height 23 mm; diameter of peristome 19.7 mm; diameter of apical system 8 mm.

Occurrence.—Texas: Nueces River 1.7 miles below the Uvalde-Eagle Pass road crossing, Uvalde County, (U.S.G.S. 11347, L. W. Stephenson).

Geologic horizon.—Lower part of the Escondido formation, of Maestrichtian age.

Type.—U.S.N.M. 108369.

Remarks.—This species is known only from the type. It differs from *Codiopsis doma* (Desmarest) in its smaller peristome, in the smaller number of its interambulacral primary tubercles and in the parallelism of its rows of ambulacral primary tubercles. The presence of small secondary tubercles set in shallow areoles probably is distinctive. These features distinguish it also from *Codiopsis texana* Whitney (1916, p. 91, pl. 17, figs. 1–4) from the Buda limestone (Cenomanian). *Codiopsis stephensoni* is much larger than the type of the Cuban *C. ciai* Lambert (*C. arnaudi* Cotteau, Egozcue y Cía, 1897, p. 14, pl. 1, figs. 10–15), and its rows of interambulacral primary tubercles are V-shaped rather than U-shaped.

Genus RACHIOSOMA Pomel

Cyphosoma (part) of early authors.

Rachiosoma Pomel, 1883, Classification méthodique et genera des échinides, p. 91.

Rachiosoma Pomel. Lambert, 1897, Soc. géol. France Bull., ser. 3, tome 25, p. 498.

Rachiosoma Pomel. Lambert and Thiéry, 1910, Essai de nomenclature raisonnée des échinides, fasc. 3, p. 221.

Rachiosoma Pomel. Mortensen, 1935, Monograph of the Echinoidea, vol. 2, p. 476.

Pomelechinus Checchia-Rispoli, 1946, Italy, R. ufficio geol. Boll., vol. 59, p. 115.

Type species, *Cyphosoma delamarrei* Deshayes, first species, designated by Lambert and Thiéry (1910, p. 221). This species has been figured by Desor (1855–1858, p. 90, pl. 15, figs. 5–7, as *Phymosoma*) and by Cotteau (1861–1867, p. 588, pl. 1140, 1141, figs. 1–3). These figures show it to have a rather small pentagonal, monocyclic apical system. The poriferous zones are uniserial throughout, the rows of zygopores curving slightly around each tubercle. Each area has two staggered rows of primary tubercles, which are imperforate and crenate. The peristome is rather large and plainly notched.

Rachiosoma differs from *Phymosoma* chiefly in that its poriferous zones are not plainly biserial on the upper surface, though some species are described as showing a tendency to become biserial near the apical system. The apical system of *Rachiosoma delamarrei* is much smaller than the apical scar of *Phymosoma konigii* (Mantell), the type species of *Phymosoma*, the arrangement of whose apical plates is unknown. *Rachiosoma* has a relatively smaller peristome than *Porosoma* Cotteau 1856.

The name *Pomelechinus* was proposed to replace *Rachiosoma* on the supposition that it is a homonym of *Rhachiosoma* Woodward, 1871, but both names are acceptable under Article 35 of the International Rules.

Rachiosoma hondoensis Cooke, n. sp.

Plate 3, figures 4, 5

Test low hemispherical. Apical system large, probably pentagonal. Ambulacra wide; poriferous zones polyporous, zygopores arranged in slightly curved or broken arcs, apparently about five to each plate; decorated with two rows of rather large primary, smooth, imperforate tubercles, whose areoles are tangent below the ambitus but separated above it; partial rings of small tubercles encircling the primaries separate the rows but are absent elsewhere below the ambitus. Interambulacra having two rows of primary tubercles bordered on each side by a row of smaller tubercles and separated by large granules. Peristome round, strongly notched, less than half as wide as the horizontal diameter.

Horizontal diameter 39 mm; height more than 18 mm; diameter of peristome 15.7 mm.

Occurrence.—Texas: Blue Water Hole, Hondo Creek, 0.5 to 0.75 mile above the Elstone-Biry road crossing, Medina County, (U.S.G.S. 7686, L. W. Stephenson).

Geologic horizon.—Escondido formation.

Type.—U.S.N.M. 108371.

Remarks.—Only one specimen is known, and it has lost most of the upper side. It is referred to *Rachiosoma* rather than to *Porosoma* because of the greater size of its apical scar. *Rachiosoma hondoensis* appears to be a taller, less disc-shaped species than *R. mortoni* (de Loriol) and grew much larger than the few known specimens of that species.

***Rachiosoma mortoni* (de Loriol)**

Plate 1, figures 12, 13

Cyphosoma mortoni De Loriol, 1887, Recueil zool. suisse, tome 4, no. 3, p. 389, pl. 17, figs. 2a-c.

Coptosoma mortoni (De Loriol). Clark, 1893, U. S. Geol. Survey Bull. 97, p. 51, p. 17a-e.

Coptosoma mortoni (De Loriol). Clark, 1915, U. S. Geol. Survey Mon. 54, p. 62, pl. 22, figs. 1a-e.

Test wheel-shaped, slightly depressed around the peristome. Apical system unknown, scar pentagonal. Peristome more than one-third the total width; notches sharp but not very deep. Ambulacra two-thirds as wide as the inter-ambulacra; poriferous zones undulating, especially near the ambitus, uniserial throughout. Tubercles imperforate, decreasing in size regularly away from the ambitus, one to each plate, thus forming two rows in each area, strongly mammillated. Intermediate areas covered with coarse granules except the median parts of the interambulacral areas near the apical scar, which are nearly bare.

Diameter of figured specimen 23.3 mm; height 9.8 mm; width of peristome 8.5 mm.

Occurrence.—Mississippi: Wahalak (misspelled Nahalak) Kemper County (type, Professor Wetherby, *vide* de Loriol).

Alabama: Chattahoochee River between the mouth of Cowikee Creek and Eufaula (U.S.G.S. 850, T. W. Stanton, figured specimen).

Geologic horizon.—Probably Ripley formation.

Type.—DeLoriol collection. Figured specimen U.S.N.M. 108370.

Comparisons.—This species appears to be very similar to *Rachiosoma delamarrei* (Deshayes) as figured by Cotteau (1861-1867, p. 588, pl. 1140) though its granulation may be denser. It is lower and smaller than *R. hondoensis* Cooke, n. sp., and its poriferous zones, though undulating, are not broken into separate arcs. It is assigned to *Rachiosoma* rather than to *Porosoma* because its peristome is smaller than that of *Porosoma cribrum*, the type of *Porosoma* (Mortensen, 1935, p. 474, fig. 275).

Genus PHYMOSOMA D'Archiac and Haime

Cyphosoma Agassiz, 1838, Monographies d'échinodermes, Mon. 1, p. 4. Not *Cyphosoma* Mannerheim, 1837.

Cyphosoma Agassiz. Agassiz, 1840, Catalogus systematicus ectyporum echinodermatum, pp. 11, 19.

Phymosoma D'Archiac and Haime, 1853, Description des animaux fossiles de l'Inde, p. 197. For *Cyphosoma* Agassiz.

Phymosoma Haime. Mortensen, 1935, Monograph of the Echinoidea, vol. 2, p. 486. (Gives additional synonymy.)

Phymosoma D'Archiac and Haime. Cooke, 1941, Jour. Paleontology, vol. 15, no. 1, p. 17.

Phymosoma D'Archiac and Haime. Cooke, 1946, Jour. Paleontology, vol. 20, no. 3, p. 209.

Type species *Echinus milleri* Desmarest 1825 = *Cidaris konigii* Mantell 1822, from the Chalk of Kent, England, first species, designated by Savin (1903, p. 169). This species has been figured by Cotteau (1861-1867, p. 678, pl. 1167, 1168) and by Wright (1870, p. 131, pls. 23-26). It has a large pentagonal apical scar and a comparatively small circular peristome with rather weak notches. Its poriferous zones are biserial above the ambitus and uniserial in arcs below it. Its tubercles are imperforate.

Dixieus Cooke (1948, p. 607) has these features, but its apical system is much smaller, its peristome much larger, and it has twice as many pores.

***Phymosoma hilli* (Clark)**

Plate 3, figures 6, 7

Pseudodiadema hilli Clark, 1891, Johns Hopkins Univ. Circ. vol. 10, no. 87, p. 76.

Diplopodia hilli (Clark). Clark, 1893, Johns Hopkins Univ. Circ., vol. 12 no. 103 p. 51.

Diplopodia hilli (Clark). Clark, 1893, U. S. Geol. Survey Bull. 97, p. 50. Not pl. 16, figs. 2a-g.

Diplopodia hilli (Clark). Cragin, 1893, Texas Geol. Survey 4th Ann. Rept. p. 147.

Cyphosoma hilli (Clark). Clark, 1915, U. S. Geol. Survey Mon. 54 p. 59. Not pl. 19 figs. 2a-g.

Tetragramma? hilli (Clark). Adkins, 1928, Texas Univ. Bull. 2838 p. 275.

Test subpentagonal, disc-shaped, with rounded margin. Apical scar large, pentagonal, longer than wide, the posterior point leading into a depressed area. Ambulacra more than half as wide as interambulacra: poriferous zones biserial on upper surface nearly to margin, uniserial below margin. Peristome nearly half as wide as the diameter of the test; conspicuously notched. Tubercles imperforate, crenate; increasing regularly in size toward the margin; two rows at margin in ambulacra, four rows in interambulacra; spaces between primary tubercles covered with much smaller tubercles except median interambulacral bare spaces near the points of the apex.

Diameter of largest type 32 mm; height 12.7 mm; length of apical scar 12 mm; width of apical scar 9.7 mm; diameter of peristome about 14.2 mm.

Occurrence.—Texas: Bell County.

Geologic horizon.—Unknown; formations exposed in Bell County range in age from the Trinity group of the Comanche series to the upper part of the Taylor marl of the Gulf series.

Type.—U.S.N.M. 8311.

Remarks.—The preceding description is based on the largest of three type specimens in the United States National Museum numbered 8311 and labeled Bell County, Tex. A later label specifies Austin chalk. The record book states that they were collected by D. H. Walker in 1880 in Bell County, and other fossils in the same collection represent several horizons, none of which are named. Clark's original description states the locality and horizon as Austin limestone Tex. His later (1915) mono-

graph specifies Austin, Tex., Austin chalk. His drawings evidently do not represent this species, for they are intermediate in size and show perforate tubercles whereas the tubercles of the type specimens are plainly imperforate.

Genus LANIERIA Duncan

- Lanieria* Duncan 1891, Linnean Soc. London Jour., Zoology, vol. 23, p. 168.
Lanieria Duncan. Lambert, 1911, Mus. royal Histoire nat. Belgique Mém., tome 4, Année 1910, p. 28.
Lanieria Duncan. Hawkins, 1912, Zool. Soc. London Proc. 1912, pt. 2, p. 450.
Lanieria Duncan. Hawkins, 1913, Geol. Mag., dec. 5, vol. 10, p. 199.
Lanieria Duncan. Lambert and Thiéry, 1914, Essai de nomenclature raisonnée des échinides, fasc. 4, p. 285.
Lanieria Duncan. Hawkins, 1920, Royal Soc. London Philos. Trans. (B), vol. 209, p. 441.
Lanieria Duncan. Jackson, 1922, Carnegie Inst. Washington Pub. 306, p. 28.
Lanieria Duncan. Sanchez Roig, 1926, Cuba, Bol. Minas, no. 10, p. 44.
Hawkensia Lambert, 1928, Soc. géol. France Bull., ser. 4, tome 28, p. 20.
Hawkensia Lambert. Lambert, 1931, Soc. géol. France Bull., ser. 5, tome 1, p. 302.
Lanieria Duncan. Jeannet, 1936, Eclogae geol. Helvetiae, vol. 29, no. 2, p. 581.
Lanieria Duncan. Mortensen, 1948, Monograph of the Echinoidea, vol. 4, pt. 1, p. 54.

Test subglobose, depressed around the peristome. Apical system containing five perforated genital plates, with central madreporite. Ambulacral areas straight, continuous, uniserial, with many long, narrow plates. Peristome central, circular, plainly notched, less than one-third as wide as the horizontal diameter, having vestigial internal ridges radiating from the auricles. Periproct large, pyriform, basal.

Type species *Echinoconus lanieri* Cotteau (1881), by monotypy, from the Upper Cretaceous of Cuba.

Lanieria appears to be intermediate between *Holectypus* (*Cænholectypus*) and *Discoidea*, both of which it resembles in external features, though its ambulacra tend to be more complicated. It differs from *Holectypus* by having incipient internal ridges radiating from the peristome. These ridges are much less conspicuous than those of *Discoidea*, which are longer. A further difference is the greater inflation of the oral side, which contrasts with the nearly flat base of most species of *Discoidea* and to a less degree of *Holectypus*.

Lanieria uvaldana Cooke, n. sp.

Plate 3, figures 1-3

Test subglobular, slightly depressed around the peristome; horizontal outline circular to subpentagonal. Apical system containing five perforated genital plates with central madreporite; ocular plates insert, that is, touching the madreporite. Ambulacra about half as

wide as interambulacra, consisting of many straight, very narrow plates each with only one zygopore; poriferous zones straight, continuous from apical system to peristome. Interambulacral areas composed of straight plates about five times as wide as those of the ambulacra. Base closely covered with rather large perforated scrobiculate tubercles, which form transverse rows. Peristome one-third as wide as the horizontal diameter, circular, having rather deep notches. Periproct large pyriform, flush, extending nearly from the peristome to the ambitus, not visible from above.

Height 17 mm; length 27.7 mm; width 27 mm; diameter of peristome 9 mm.

The peristome and periproct of *Lanieria uvaldana* are more than twice as large as those of *L. lanieri*, and its ambulacral areas show no tendency to have compound plates. Whether it has internal partitions is unknown. The peristome and periproct are similar to those of *Holectypus* (*Coenholectypus*) *planatus* Roemer, but the base is much more rounded. The species is referred to *Lanieria* rather than to *Holectypus*, which it otherwise closely resembles, primarily because of its subglobular shape.

Occurrence.—Texas: Bluff on Turkey Creek at Lithocarbon (Carbonville, 6 miles southeast of Cline), Uvalde County, (U.S.G.S. 1771, T. W. Vaughan; Hill's No. 358, T. Corbur Asphalt Company mine 17 miles west of Uvalde, Tex., R. T. Hill).

Geologic horizon.—Probably Anacacho limestone.

Type.—U.S.N.M. 108372.

Paratypes.—Fifteen topotypes, all more or less fragmentary, and one from Hill's locality 358.

Genus CONULUS Leske

- Conulus* Leske, 1778, Klein's Naturalis dispositio Echinodermatum, p. 161.
Galerites (part) Lamarck, 1816, Histoire naturelle des animaux sans vertèbres, tome 3, p. 19; ed. 2, 1840, tome 3, p. 305.
Pyrina (part) Desmoulins, 1935, Études sur les échinides, p. 26.
Galerites Lamarck. Desor, 1842, Mon. d'échinodermes, Mon. 3, Des galérites, p. 7.
Pyrina Desmoulins. Desor, 1842, Mon. d'échinodermes, Mon. 3, Des galérites, p. 25.
Galerites Lamarck. Agassiz and Desor, 1847, Catalogue raisonné des échinodermes, p. 90.
Galerites Lamarck. Desor, 1857, Synopsis des échinides fossiles, p. 181.
Echinoconus Breynius. D'Orbigny, 1860, Paléontologie française, Terrain crétacé, ser. 1, tome 6, p. 496.
Echinoconus Breynius. De Loriol, 1873, Échinologie helvétique, pt. 2, Période crétacé, p. 190.
Echinoconus Breynius. Wright, 1873, British fossil Echinodermata from the Cretaceous formations, vol. 1, p. 213.
Echinoconus (*Galerites*) Lamarck. Pomel, 1883, Classification méthodique et genera des échinides, p. 74.
Echinoconus Breynius. Duncan, 1889, Linnean Soc. London Jour. (Zoology), vol. 23, p. 167.
Conulus Leske. Hawkins, 1911, Geol. Magazine, new ser., dec. 5, vol. 8, no. 2, p. 70.

- Conulus* Leske. Jackson in Zittel (Eastman), 1913, Textbook of paleontology, vol. 1, p. 284.
- Conulus* Klein. Lambert and Thiéry, 1914, Nomenclature raisonnée des échinides, fasc. 4, p. 283.
- Conulus* Leske. Hawkins, 1917, Geol. Magazine, new ser., dec. 6, vol. 4, no. 5, pp. 196, 433.
- Conulus* Leske. Hawkins, 1919, Geol. Magazine, new ser., dec. 6, vol. 6, no. 10, p. 442.
- Conulus* Leske. Jackson, 1922, Carnegie Inst. Washington Pub. 306, p. 27.
- Conulus* Klein. Sanchez Roig, 1926, Equinodermos fósiles de Cuba, p. 44.
- Conulus* Klein. Smiser, 1935, Mus. royal d'histoire nat. de Belgique, Mém. 68, p. 38.
- Gonulus* Klein. Mortensen, 1948, Monograph of the Echinoidea, vol. 4, pt. 1, p. 42. (Misprint for *Conulus*.)

Type species *Conulus albogalerus* Leske, by monotypy, from the Senonian of Europe and the Lower Chalk of England. This well-known species, which has been figured under the name *Echinoconus conicus* by D'Orbigny (1854-1860, p. 513, pls. 996, 997, figs. 1-7) and Wright (1864-1882, p. 221, pl. 49, figs. 2-4; pl. 50, figs. 1-6), is tall, subconical, flattened underneath. Its posterior ocular plates are in contact, and it has only four genital plates. Its ambulacra are narrow; its poriferous zones are continuous but are arranged in markedly oblique triads on the lower surface. Its peristome is central, rather small, nearly circular but according to Hawkins (1919, p. 444) always to some degree oblique. Its periproct is pyriform, submarginal, and tilted at an angle of nearly 45°. Its tubercles, which are set in deep pits, are widely separated near the apex but much closer together on the lower surface.

Conulus and *Globator* seem to be closely related. The most conspicuous differences are the location and position of the periproct, which is terminal and erect in *Globator*, submarginal and inclined in *Conulus*. A more obscure difference, which may not be constant, is the arrangement of the genital plates. In *Conulus* the posterior genital plates are usually in contact, whereas in *Globator* they are separated by the madreporite, which is more nearly central. The ambulacra of *Conulus* are commonly narrower than those of *Globator*, and the triads of pore pairs are more oblique and extend farther from the peristome.

Conulus stephensoni Cooke, n. sp.

Plate 3, figures 8-13

Test large; horizontal outline subpentagonal to ovate, broadest at the anterior paired ambulacra; upper surface moderately inflated; lower surface nearly flat; margin rounded. Apical system central; ocular plates large, the posterior pair in contact; only four genital plates, the posterior pair in contact, confining the madreporite to the anterior part of the system. Ambulacra narrow, one-third as wide as the interambulacra;

poriferous zones continuous, divided into oblique triads on the under surface. Peristome nearly symmetrical, but longer axis turned clockwise with respect to the longitudinal axis of the test. Periproct large, lenticular, inframarginal, extending halfway to the peristome, not visible from above. Tubercles large, in deep pits, not very close together on the under side, still farther apart on the upper.

Length of type 46 mm; width 41.4 mm; height 24.4 mm. Length of paratype 51.8 mm; width 45.9 mm, height 26 mm.

Occurrence.—Texas: Crest of north-facing slope of Medio Creek Valley on a second-class road on the Burrell ranch, about 1 mile northeast of Padrone Hill, 13 miles west of San Antonio, Bexar County (U.S.G.S. 15626, type, L. W. Stephenson and A. N. Sayre; U.S.G.S. 16880, paratype, L. W. Stephenson). Sabinal-Utopia road 5½ miles north of Sabinal, Uvalde County (U.S.G.S. 7711, L. W. Stephenson). Connor's ranch on Rio Frio 0.5 mile above Engleman's ranch, Uvalde County (U.S.G.S. 10881, L. W. Stephenson). Road leading from Engleman's old ranch house to the new (U.S.G.S. 13778, J. T. Lonsdale).

Geologic horizon.—Austin chalk, upper part, of early Senonian (Santonian) age.

Type.—U.S.N.M. 108373; paratype 108374.

Comparisons.—*Conulus stephensoni* differs from *Globator vaughani* Cooke in its greater size, in its less rotund shape, in details of the arrangement of its apical plates, in the location of its periproct, in the wider spacing of its tubercles, and in the narrowness of its ambulacra.

Genus *GLOBATOR* Agassiz

- Globator* Agassiz, 1840, Catalogus systematicus ectyporum Echinodermatum, pp. 7, 16.
- Pyrina* Desmoulins. Agassiz, 1840, Catalogus systematicus ectyporum Echinodermatum, pp. 7, 16.
- Globator* Agassiz. Desor, 1842, Mon. d'échinodermes, Mon. 3, Des galérites, p. 30.
- Globator* Agassiz. Agassiz and Desor, 1847, Catalogue raisonné des échinodermes, p. 92.
- Globator* Agassiz. Desor, 1858, Synopsis des échinides fossiles, p. 186.
- Pyrina* Desmoulins. Desor, 1858, Synopsis des échinides fossiles, p. 190.
- Pyrina* Desmoulins. D'Orbigny, 1860, Paléontologie française, Terrain crétacé, tome 6, p. 462.
- Pyrina* Desmoulins. De Loriol, 1873, Échinologie helvétique, pt. 2, Échinides de la période crétacée, p. 200.
- Pyrina* Desmoulins. Wright, 1875, British fossil Echinodermata from the Cretaceous formations, vol. 1, pt. 7, p. 235.
- Pyrina* Desmoulins. Pomel, 1883, Classification méthodique et genera des échinides, p. 53.
- Pyrina* (*Nucleopyrina*) Pomel, 1883, Classification méthodique et genera des échinides, p. 53.
- Pyrina* (*Globator*) Agassiz. Pomel, 1883, Classification méthodique et genera des échinides, p. 53.
- Pyrina* Desmoulins. Cotteau, 1887, Paléontologie française, Terrain tertiaire, tome 1, p. 455.
- Pyrina* Desmoulins. Duncan, 1889, Linnean Soc. London Jour., Zoology, vol. 23, p. 172.
- Pseudopyrina* Lambert, 1908, Assoc. française avanc. sci. Compte rendu 36me ses. (Rheims, 1907), p. 286.

- Pyrina* Desmoulins. Lambert and Thiéry, 1914, Nomenclature raisonnée des échinides, fasc. 4, p. 284.
- Pyrina* Desmoulins. Hawkins, 1919, Geol. Mag., ser. 6, vol. 6, p. 442.
- Globator* Agassiz. Lambert and Thiéry, 1921, Nomenclature raisonnée des échinides, fasc. 5, p. 328.
- Globator* (*Pseudopyrina*) Lambert. Lambert and Thiéry, 1921, Nomenclature raisonnée des échinides, fasc. 5, p. 329.
- Pseudopyrina* Lambert. Adkins, 1928, Texas Univ. Bull. 2838, p. 283.
- Globator* (*Pseudopyrina*) Lambert. Smiser, 1935, Mus. royal d'histoire nat. Mém. 68, p. 41.
- Globator* (*Pseudopyrina*) Lambert. Smiser, 1936, Jour. Paleontology, vol. 10, no. 6, p. 463.
- Globator* Agassiz. Cooke, 1946, Jour. Paleontology, vol. 20, no. 3, p. 220.
- Pyrina* Desmoulins. Mortensen, 1948, Monograph of the Echinoides, vol. 4, pt. 1, p. 85.

Type species *Globator nucleus* Agassiz, by monotypy.

Many authors have regarded *Globator* as a synonym of *Pyrina* Desmoulins 1835 on the erroneous assumption that the type of *Pyrina* is *P. petricoriensis* Desmoulins = *Globator petricoriensis* Agassiz (Agassiz and Desor, 1847, p. 92). However, *Pyrina petricoriensis* was a *nomen nudum* when first listed by Desmoulins in 1835. As was pointed out by Desor (1842, p. 25) and by Cooke (1946, p. 220), of the seven species or nominal species originally referred to *Pyrina* by Desmoulins, only *Galerites rotula* Brongniart, *Nucleolites depressa* Brongniart, and *Nucleolites castanea* Brongniart were known by descriptions and figures. Desor (1842, p. 25) definitely fixed the type of *Pyrina* as *Nucleolites depressa* by the words " * * * il n'y aurait que l'espèce figurée par Brongniart sous le nom de *Nucleolites depressa* qui pût rester dans le genre *Pyrina*." Cooke (1946, p. 220), overlooking this previous designation, designated *Nucleolites castanea* as the type species of *Pyrina*. Both of these species were referred by Cotteau (D'Orbigny, 1854-1860, pp. 472-474, footnotes), who examined the types, to the genus *Echinoconus* Breynius now called *Conulus*. *Pyrina* Desmoulins 1835, therefore, becomes a synonym of *Conulus* Leske 1778.

As figured by Desor (1842, p. 30, pl. 3, figs. 1-4) and by D'Orbigny (1854-1860, p. 489, pl. 987, figs. 1-5) *Globator nucleus* is rather small (18 mm long), nearly globular, slightly flattened or concave around the peristome, which is angular and oblique; the periproct is terminal, longitudinally elongated, and rather large. Desor describes the apical system as having only four genital plates, which are plainly perforated. The five ocular plates are as large as the genitals, but their perforations are very minute. Desor knew of only one specimen, the type, in the Deshayes collection. Its source was unknown, but he was sure that it is a Cretaceous fossil. The specimen figured by D'Orbigny,

which closely resembles Desor's figures, is reported from the Senonian of Ciply, Belgium. *Globator nucleus* should not be confused with *Conulus nucula* (Albin Gras) (D'Orbigny, 1854-1860, p. 508, pl. 992, figs. 1-5; Smiser, 1935, p. 39, pl. 3, figs. 6a-d). According to the figures, *G. nucleus* differs in the elongation and obliquity of its peristome and in the terminal location of its periproct, though the general appearance of the two species is similar.

Apparently *Globator* differs from *Conulus* in that its posterior genital plates are separated by the madreporite, whereas the plates are in contact in *Conulus*. A further, more conspicuous difference is that its periproct is terminal and vertical, not inframarginal and nearly horizontal as in *Conulus*. *Globator* commonly has wider ambulacra.

Globator vaughani Cooke, n. sp.

Plate 4, figures 1-4

Test medium-sized, inflated, longer than wide, widest in front of the center, lower surface flattened, slightly concave around the peristome. Apical system central; ocular plates relatively large, the two posterior plates in contact; only four genital plates, the madreporite central. Ambulacra about half as wide as the interambulacra; poriferous zones straight, narrow, continuous, broken into slightly inclined triads near the peristome. Peristome assymmetrical, longest dimension turned clockwise from the longitudinal axis. Periproct large, pyriform, terminal. Tubercles widely scattered on upper surface, larger and closer on the lower surface, in deep pits.

Length 27.5 mm; width 24 mm; height 15 mm.

Occurrence.—Texas: Turkey Creek bluff, Lithocarbon (Carbonville), Uvalde County, 6 miles southeast of Cline station (type, U.S.G.S. 1771, T. W. Vaughan); T. Corbur Asphalt Company's mine, 17 miles west of Uvalde (Hill's no. 358, R. T. Hill).

Geologic horizon.—Anacacho limestone.

Type.—U.S.N.M. 108375.

Comparisons.—This species, which is represented by 39 individuals, has little variation in shape. It is less globose than *Globator nucleus* and is narrower behind than *G. cylindrica* (Albin Gras) and *G. ataciana* (Cotteau) as figured by D'Orbigny (1854-1860, p. 979; 988, figs. 1-5). It is more inflated and less symmetrical than *Globator desmoulinsii* (D'Archiac) as figured by Smiser (1935, pl. 4, figs. 2a-g). All these species are represented as having terminal periprocts similar in location, size and shape.

Genus *NUCLEOPYGUS* L. Agassiz

Nucleopygus L. Agassiz, 1840, Catalogus systematicus ectyporum echinodermatum, p. 7, 16.

Nucleopygus (Agassiz). Desor, 1842, Monographies d'échinodermes, Mon. 3, Galérites, p. 32.

Nucleopygus (Agassiz). Desor, 1856, Synopsis des échinides fossiles, p. 188.

Pyrina (*Nucleopygus*) Agassiz. Pomel, 1883, Classification méthodique et genera des échinides, p. 54.

- Pyrina* (*Nucleopygus*) Agassiz. Duncan, 1889, Linn. Soc. London Jour. (Zoology), vol. 23, p. 173.
- Nucleopygus* Agassiz. Savin, 1903, Soc. hist. nat. Savoie Bull., ser. 2, tome 8, p. 121.
- Porobrissus* Lambert, 1916, Rev. crit. de paléozoologie, tome 20, p. 169, type *Echinobrissus angustatus* Clark.
- Nucleopygus* Agassiz. Lambert and Thiéry, 1921, Nomenclature raisonnée des échinides, fasc. 5, p. 347.
- Nucleopygus* Agassiz. Smiser, 1935, Mus. royal d'histoire nat. de Belgique Mém No. 68, p. 51.
- Nucleopygus* Agassiz. Mortensen, 1948, Monograph of the Echinoidea, vol. 4, pt. 1, p. 185.

Type species *Nucleopygus minor* L. Agassiz, designated by Lambert and Thiéry (1909–1925) and by implication by Desor (1842). The only other species mentioned by Agassiz is *N. incisus*, which Desor supposed probably represented a different genus. As described and figured by Desor (1842, p. 33, pl. 5, figs. 20–22) *Nucleopygus minor* is a small, oval form with rounded contours and truncated behind. Its ambulacra are very narrow and probably subpetaloid. Its peristome is deeply sunken and without floscelle. Its periproct is large, pyriform, and opens at the bottom of a wide furrow near the apex. D'Orbigny (1854–1860, p. 492, pl. 988, figs. 6–10) transferred it to *Pyrina*, but it differs from other species referred by him to *Pyrina* in the narrowness of its petals.

To *Nucleopygus* probably should be referred *Echinobrissus angustatus* Clark (1915, p. 69, pl. 27, figs. 2a–c), which became the type of *Porobrissus* but was later transferred to *Clypeopygus* by Lambert and Thiéry (1909–1925, p. 348; Cooke, 1946, p. 222, pl. 31, figs. 10–12).

Nucleopygus texanus (Clark)

Plate 4, figures 5–7

- Echinobrissus texanus* Clark, 1891, Johns Hopkins Univ. Circ., vol. 10, no. 87, p. 76.
- Echinobrissus texanus* Clark. Clark, 1893, Johns Hopkins Univ. Circ., vol. 12, no. 103, p. 52.
- Echinobrissus texanus* Clark. Clark, 1893, U. S. Geol. Survey Bull. 97, p. 62, pl. 26, figs. 2a–f.
- Echinobrissus texanus* Clark. Clark, 1915, U. S. Geol. Survey Mon. 54, p. 70, pl. 28, figs. 2a–f.

Horizontal outline ovate, wider behind; upper surface moderately swollen; lower surface deeply concave around the peristome; margin broadly rounded. Apical system in front of the center; four genital pores and a central madreporite. Ambulacra narrow, straight, subpetaloid, petals apparently extending halfway to the margin. Peristome slightly in front of the center; deeply sunken; without floscelle. Periproct large, oval, about midway between the apex and the margin, sunken in a shallow depression, which extends to the margin but does not indent it. Tubercles scrobiculated, large and sparse on upper surface, smaller and closer underneath.

Length of type 19 mm; width 16.6 mm; height 9 mm.

Occurrence.—Texas: South side of the Colorado River at Austin (type, U.S.G.S. 768, T. W. Stanton). Shoal Creek, Travis County (U.S.N.M. 12241).

Geologic horizon.—Austin chalk, probably lower part, of Coniacian age.

Type.—U.S.N.M. 20266.

Remarks.—This species is known only from the type and one other specimen, which is partly embedded in hard matrix. Clark's drawings show the type with too small a peristome and periproct because those features were partly embedded in chalky limestone, which has since been removed. The peristome is partly broken, but it seems to have had rounded contours and to have been somewhat wider than long.

The type of *Nucleopygus texanus* is about twice as large as that of *N. minor*; it is not so conspicuously truncated behind, its periproct is more symmetrical, and apparently its sulcus is deeper. It is somewhat larger than *N. angustatus* (Clark), its peristome is deeper, its periproct is much larger, and its greatest width is farther forward.

It is much smaller than the types of *Echinobrissus expansus* Clark (1915, p. 69, pl. 28, figs. 1a–g), its periproct is smaller, and its sulcus does not indent the margin. The types of that species, from an unknown locality, appear to be *Nuculites scutata* (Lamarck), a European Jurassic species.

Genus FAUJASIA D'Orbigny

- Faujasia* D'Orbigny, 1856, Paléontologie française, Terrain crétacé, ser. 1, tome 6, pp. 290, 314.
- Faujasia* D'Orbigny. Desor, 1858, Synopsis des échinides fossiles, p. 316.
- Faujasia* D'Orbigny. Cotteau and Triger, 1869, Échinides du département de la Sarthe, p. 426.
- Faujasia* D'Orbigny. Pomel, 1883, Classification méthodique et genera des échinides, p. 66.
- Faujasia* D'Orbigny. Duncan, 1889, Linnean Soc. London Jour., Zoology, vol. 23, p. 189.
- Faujasia* D'Orbigny. Lambert and Thiéry, 1921, Essai de nomenclature raisonnée des échinides, fasc. 5, p. 373.
- Faujasia* D'Orbigny. Smiser, 1935, Mus. royal d'histoire nat. Belgique Mem., no. 68, p. 64.
- Faujasia* D'Orbigny. Mortensen, 1948, Monograph of the Echinoidea, vol. 4, pt. 1, p. 163.

Type species, *Pygurus apicalis* Desor (Agassiz and Desor, 1847, p. 104), from the Maestrichtian, designated by Lambert and Thiéry (1909–1925, p. 373). This species has been figured by Desor (1855–1858, p. 317, pl. 33, figs. 1–4), D'Orbigny (1854–1860, p. 315, pl. 922), Smiser (1935, p. 65, pl. 6, figs. 8a–d), and Mortensen (1948, p. 164, fig. 136). It is subquadrate in horizontal outline, swollen and commonly pointed on top, flat below, with sharply rounded margin. It has four genital pores, short lanceolate petals, with poriferous zones nearly closed at each end and with elongated outer pores and round inner pores. Its peristome is central and is surrounded by a conspicuous floscelle with rounded bourrelets. Its periproct is transversely elongated, on the oral side, nearly terminal, but not visible from above.

Echinolampas faujasii Desmoulins might better have been selected as the type by virtual tautonymy rather than *Pygurus apicalis*, the first species. However, it makes little practical difference, for these species are very similar.

Faujasia chelonium Cooke, n. sp.

Plate 4, figures 11-14

Test medium-sized; upper surface tumid, lower surface slightly concave, expanded and turned down at the margin; horizontal outline semicircular in front, sides straight, V-shaped behind; margin sharp. Apical system central, monobasal (plates fused), with four genital pores. Petals lanceolate, nearly equal in length, extending little more than halfway to the margin; poriferous zones nearly closed at the outer ends, somewhat wider open at the inner ends; pores conjugate, those of outer row slightly elongate, inner row circular, zygopores oblique with respect to the median suture of the petal. Peristome central; bourrelets long and pointed like those of *Hardouinia*; phyllodes longer than wide. Periproct transversely elongated, small, terminal, indenting the margin as viewed from above but turned slightly downward.

Length 30.5 mm; width 28 mm; height 16 mm.

Occurrence.—Texas: Indio Ranch half a mile from the Rio Grande, in Maverick County (U.S.G.S. 10854, L. W. Stephenson).

Geologic horizon.—Escondido formation of Maestrichtian age.

Type.—U.S.N.M. 108377.

Remarks.—The specific name is a Latin noun meaning, literally, a tortoise shell.

The unique type of *Faujasia chelonium* is only about half as large as that of *Pygurostoma geometricum*. Its outer pores are less elongated, its posterolateral sides are straighter, its margin is more expanded, its periproct is more nearly terminal, and its bourrelets appear to be flatter. Its petals are longer and broader, its margin more expanded, its periproct is more nearly terminal, and its bourrelets are more pointed than the corresponding features of *Faujasia apicalis*.

Genus PYGUROSTOMA Cotteau and Gauthier

Pygurostoma Cotteau and Gauthier, 1895, De Morgan's Mission sci. en Perse, tome 3, pt. 2, p. 51.

Pygurostoma Cotteau and Gauthier. Lambert and Thiéry, 1921, Nomenclature raisonnée des échinides, fasc. 5, p. 357.

Pygurostoma Cotteau and Gauthier. Mortensen, 1948, Monograph of the Echinoidea, vol. 4, pt. 1, p. 244.

Type species *Pygurostoma morgani* Cotteau and Gauthier (1895, p. 52, pl. 8, figs. 1-5) from the Senonian at Aftâb, Louristan, Persia, by monotypy. Four of the five original figures of this species are copied by Mortensen (1948, p. 245, figs. 228, 229). *P. morgani* has an oval outline, a gently convex upper surface, a rounded margin, and a somewhat concave lower surface. It has a large central madreporite with four genital pores. Its petals are rather long and are open at the ends. It has

a large floscelle with rounded bourrelets. Its periproct is submarginal, sloping, longitudinally oval. Its tubercles appear to be deeply sunken, much larger on the lower surface.

Pygurostoma geometricum (Morton)

Plate 4, figures 15-20

Clypeaster geometricus Morton, 1833, Am. Jour. Sci., ser. 1, vol. 24, p. 131, pl. 10, fig. 9.

Clypeaster geometricus Morton. Morton, 1834, Synopsis of the organic remains of the Cretaceous group, p. 76, pl. 10, fig. 9.

Pygurus geometricus (Morton). D'Orbigny, 1856, Paléontologie française, Terrain, crétacé, tome 6, p. 313, pl. 920, fig. 4. Copies Morton's figure.

Pygurus geometricus (Morton). Desor, 1858, Synopsis des échinides fossiles, p. 313.

Pygurus geometricus (Morton). Clark, 1915, U. S. Geol. Survey Mon. 54, p. 72.

Cassidulidae, new genus (?), new species. Carter, 1937, Maryland Geol. Survey, vol. 13, p. 273.

Test large; upper surface inflated; lower surface somewhat concave; margin acutely rounded; somewhat produced behind. Apical system in front of the center, probably monobasal, with four genital pores. Petals lanceolate, equal, extending more than halfway to the margin; poriferous zones nearly closed at each end, pores strongly conjugate, outer pores elongated, inner pores round. Peristome central; bourrelets rounded at the base, hollow, probably rounded at the tips; phyllodes short and broad. Periproct small, apparently transversely oval, inframarginal, nearly terminal but not visible from above, slanting upward toward the rear.

Length of type 56.4 mm; width 54 mm; height 25 mm. Length of figured specimen 55.5 mm; width 49 mm; height 25 mm.

Occurrence.—Delaware: Delaware and Chesapeake Canal (type); north side of Chesapeake and Delaware Canal 2,000 feet east of the railroad bridge (U.S.G.S. 17753, Charles W. Carter).

Geologic horizon.—Marshalltown formation, of Campanian age.

Type.—Academy of Natural Sciences of Philadelphia no. 1496. Figured specimen U.S.N.M. 108378.

Remarks.—Carter's field label states that he found the specimen here figured in place in the Crosswicks clay, the basal formation of the Matawan group, but his published report places it in the Marshalltown formation, the upper formation of that group. This discrepancy doubtless records a change in correlation as the result of later studies.

Pygurostoma pasionense Cooke

Plate 16, figures 6-11

Pygurostoma pasionensis Cooke, 1949, Am. Mus. Novitates no. 1422, p. 1.

Horizontal outline oval, upper surface elevated, highest at the apical center, lower surface gently concave, margin rounded. Apical system slightly in front of the apical center, having a large central madreporite

and four genital pores. Petals extending more than halfway to the margin; poriferous zones open at the tips, one-third as wide as the interporiferous zones, inner pores oval, outer pores longer, pores conjugate; interporiferous zones tumid; anterior petal straighter-sided than the others. Peristome pentagonal, slightly in front of the apex, surrounded by a floscelle with round bourrelets and conspicuous phyllodes. Peristome submarginal, longer than wide. Upper surface covered with small sunken tubercles; tubercles on lower surface much larger.

Length 61 mm, width 53 mm; height 30 mm.

Occurrence.—Guatemala: Airstrip near Rio de la Pasion at Santa Amelia, Peten (U.S.N.M. accession 195206, Barnum Brown).

Geologic horizon.—Probably Campanian.

Type.—Am. Mus. Nat. History 26901. Replicas, U.S.N.M. 104914 and geological department of the Sohio Petroleum Company at Houston, Tex.

Figured specimen.—U.S.N.M. 108406.

Comparison.—*Pygurostoma passionense* is very similar to *P. morgani*. The tubercles on its lower surface are smaller than they are represented on the figures of the Persian species, which I have not seen.

Genus CATOPYGUS L. Agassiz

Catopygus L. Agassiz, 1836, Soc. nat. Neuchâtel, Mém., tome 1, pp. 136, 185.

Catopygus L. Agassiz. Agassiz, 1840, Catalogus systematicus ectyporum echinodermatum, pp. 4, 17.

Catopygus Agassiz. Agassiz and Desor, 1847, Catalogue raisonné des échinides, p. 99.

Catopygus Agassiz. Desor, 1858, Synopsis des échinides fossiles, p. 282.

Catopygus Agassiz. D'Orbigny, 1860, Paléontologie française, Terrain crétacé, ser. 1, tome 6, p. 432.

Catopygus Agassiz. Cotteau and Triger, 1869, Échinides du département de la Sarthe, p. 423.

Catopygus Agassiz. De Loriol, 1873, Échinologie helvétique, Oursins fossiles de la Suisse, pt. 2, p. 273.

Catopygus Agassiz. Wright, 1875, British fossil Echinodermata from the Cretaceous formations, vol. 1, pt. 7, p. 240.

Catopygus Agassiz. Pomel, 1883, Classification méthodique et genera des échinides, p. 64.

Catopygus Agassiz. Duncan, 1889, Linnean Soc. Jour., Zoology, vol. 23, p. 185.

Catopygus Agassiz. Lambert and Thiéry, 1921, Nomenclature raisonné des échinides, fasc. 5, p. 353.

Catopygus Agassiz. Sanchez Roig, 1926, Equinodermos fósiles de Cuba, p. 70.

Catopygus Agassiz. Smiser, 1935, Mus. royal d'histoire nat. de Belgique Mém. no. 68, p. 53.

Catopygus Agassiz. Grant and Hertlein, 1938, California Univ. Los Angeles Pub. Math. and Phys. Sci., vol. 2, p. 110.

Catopygus Agassiz. Mortensen, 1948, Monograph of the Echinoidea, vol. 4, pt. 1, p. 158.

Type species *Nucleolites carinatus* Goldfuss 1826, designated by Lambert and Thiéry, 1921. According to D'Orbigny (1854–1860, p. 436) and Wright (1864–1882, p. 241) this is a synonym of *Nucleolites columbaria*

Lamark 1816, though Cotteau (D'Orbigny, 1854–1860, p. 439, footnote), Desor, and others distinguish between them. As figured by Goldfuss (1829, pl. 4, figs. 11a–c) this species is oval in outline, high-arched above, flat below, rostrate above the terminal periproct, and truncated behind. Its apical system and peristome are in front of the center. Its petals appear to be long, wide, and open at the distal ends. The bourrelets are swollen, and the phyllodes longer than wide. The periproct is high up on the terminal truncation. As figured by Cotteau and Triger (1855–1869, p. 424, pl. 32, figs. 1–4) the periproct is barely visible from above.

Catopygus pusillus Clark

Plate 5, figures 1, 2

Catopygus pusillus Clark, 1891, Johns Hopkins Univ. Circ., vol. 10, no. 87, p. 76.

Catopygus pusillus Clark. Clark, 1893, Johns Hopkins Univ. Circ., vol. 12, no. 103, p. 52.

Catopygus pusillus Clark. Clark, 1893, U. S. Geol. Survey Bull. 97, p. 65, pl. 27, figs. 3a–d.

Catopygus pusillus Clark. Weller, 1907, New Jersey Geol. Survey, Paleontology ser., vol. 4, p. 292, pl. 11, figs. 16–19.

Catopygus pusillus Clark. Clark, 1915, U. S. Geol. Survey Mon. 54, p. 73, pl. 29, figs. 3a–d.

Phyllobrissus pusillus (Clark). Lambert and Thiéry, 1921, Nomenclature raisonnée des échinides, fasc. 5, p. 351.

Outline nearly circular; upper surface moderately inflated, rostrate behind; lower surface nearly flat; margin evenly rounded. Apical system nearly central. Petals straight, extending about halfway to the margin, open distally. Peristome not preserved. Periproct circular (?), terminal, well up on the posterior end, vertical.

Length of larger syntype 14 mm; width 13.3 mm; height 8.1 mm.

Occurrence.—New Jersey: Wordills, Monmouth County.

Geologic horizon.—Merchantville clay, of Santonian age.

Types.—U.S.N.M. 2210.

Comparisons.—This species, represented by two cotypes and one other, all casts of the interior, is proportionally shorter than *Catopygus carinatus* (Goldfuss).

Catopygus mississippiensis Cooke, n. sp.

Plate 5, figures 3–6

Outline regularly oval, strongly arched above, flattened below, margin rounded. Apical system slightly anterior; four genital pores; plates not fused. Ambulacra petaloid, petals extending more than halfway to the margin; poriferous zones nearly straight, open distally; inner pores round, outer pores oval, pores apparently conjugate. Peristome slightly anterior, pentagonal, longitudinally elongated. Phyllodes longer than wide, outlined by a curved row of very small zygopores, divided into three equal parts by two rows

of wider-spaced pores or zygopores. Bourrelets squarish, rather prominent, inner lips granulated. Periproct distorted, apparently transversely elongated; located at mid-height, at the top of a shallow depression; slightly rostrate. Tubercles on margin very small; somewhat larger underneath; separated by granules.

Length 17.5 mm; width 15.6 mm; height 11.1 mm.

Occurrence.—Mississippi: Bed of a branch stream near Mobile and Ohio Railroad tracks about 5 miles northeast of Houston (U.S.G.S. 6851, L. W. Stephenson). Clay County (Paleontological Research Laboratories, Statesville, N. C.).

Geologic horizon.—Prairie Bluff chalk, of later Maestrichtian age.

Type.—U.S.N.M. 108379.

Comparisons.—This species, known only from the type and two smaller individuals from Clay County, is more regularly oval than the European species *Catopygus carinatus* or *C. fenestratus*, and its tubercles are smaller. It is more elongated than *Catopygus williamsi* and more regularly oval than *C. pusillus* from New Jersey.

Subgenus OOLOPYGUS D'Orbigny

Oolopygus D'Orbigny, 1856, Paléontologie française, Terrain crétacé, ser. 1, tome 6, atlas, pls. 976, 977.

Oolopygus D'Orbigny. Desor, 1857, Synopsis des échinides fossiles, fasc. 5, p. 286.

Oolopygus D'Orbigny. Cotteau in D'Orbigny, 1860, Paléontologie française, Terrain crétacé, ser. 1, tome 6, p. 454.

Oolopygus D'Orbigny. Pomel, 1883, Classification méthodique et genera des échinides, p. 64.

Oolopygus (section *Penesticta*) Pomel, 1883, Classification méthodique et genera des échinides, p. 64.

Oolopygus D'Orbigny. Lambert, 1910, Soc. linnéenne Normandie Bull., ser. 6, tome 2, p. 16.

Oolopygus D'Orbigny. Lambert and Thiéry, 1921, Nomenclature raisonnée des échinides, fasc. 5, p. 354.

Oolopygus D'Orbigny. Smiser, 1935, Mus. royal d'histoire nat. Belgique Mém. no. 68, p. 57.

Catopygus (*Oolopygus*) D'Orbigny. Mortensen, 1948, Monograph of the Echinoidea, vol. 4, pt. 1, p. 160.

Type species *Nucleolites pyriformis* (Leske) Goldfuss (not *Echinites pyriformis* Leske 1778=*Catopygus pyriformis* (Leske) Agassiz 1836), from the white Chalk near Aachen, Germany, and Maestricht, Netherlands. According to Cotteau (D'Orbigny, 1854–1860, pp. 457, 458) Goldfuss' species is the same as *Catopygus tenuiporus* Agassiz (Agassiz and Desor, 1847, p. 100). Lambert (1910, p. 20) disagrees and proposes the name *Oolopygus gracilis* for the species figured by Goldfuss (1829, pl. 43, figs. 7a–c). Goldfuss' figures indicate a test about 25 mm long, rounded in front, bluntly pointed behind, moderately inflated above, flat below, rostrate above the periproct, which is terminal but not visible from above. The petals appear to be rather short, open at the distal ends, nearly equal in length. The peristome is pentagonal, in front of the center; the bourrelets swollen; and the phyllodes conspicuous, slightly longer than wide.

Oolopygus is more protracted behind than typical *Catopygus*, which is short and stubby.

Catopygus (*Oolopygus*) *williamsi* Clark

Plate 5, figures 7–10

Catopygus williamsi Clark in Weller, 1907, New Jersey Geol. Survey, Paleontology Ser., vol. 4, p. 292, pl. 12, figs. 1–4.

Catopygus williamsi Clark. Clark, 1915, U. S. Geol. Survey Mon. 54, p. 73, pl. 29, figs. 4a–d.

Catopygus williamsi (Clark). Lambert and Thiéry, 1921, Nomenclature raisonnée des échinides, fasc. 5, p. 355.

Outline rounded in front, produced and laterally truncate behind; upper surface low-convex, highest behind the center; lower surface nearly flat; margin evenly rounded. Apical system nearly central; petals narrow, extending more than halfway to the margin; poriferous zones straight, open distally, about as wide as interporiferous zones. Peristome in front of the center. Bourrelets probably high, narrow, hollow. Periproct terminal, rostrate, longitudinally elongated, visible from below.

Length 16.2 mm; width 21 mm; height 14 mm.

Occurrence.—New Jersey: Bluff east of Atlantic Highlands.

Geologic horizon.—Navesink marl of middle Maestrichtian age.

Type.—U.S.N.M. 103698 (deposited by the Johns Hopkins University, T 3010).

Comparison.—*Catopygus williamsi*, represented only by the type, a cast of the interior, appears to be very similar to the species figured by D'Orbigny (1854–1860, p. 457, pl. 977) under the name *Oolopygus pyriformis*.

Genus LEFORTIA Cossmann

Pomelia De Loriol, 1900, Rev. suisse Zoologie, tome 8, p. 66. Not *Pomelia* Zittel, 1875.

Lefortia Cossmann, 1901, Rev. crit. Paléozoologie, tome 5, p. 58. New name for *Pomelia* De Loriol. Published January 1901.

Pomeliopsis De Loriol, 1901, Notes pour servir à l'étude des échinodermes, ser. 1, fasc. 9, p. 45. New name for *Pomelia* De Loriol. Published May 1901.

Lefortia Cossmann-Lambert and Thiéry, 1921, Nomenclature raisonnée des échinides, fasc. 5, p. 363.

Lefortia Cossmann. Mortensen, 1948, Monograph of the Echinoidea, vol. 4, pt. 1, p. 251.

Type species, *Pomelia delgadoi* De Loriol, from the Senonian of Portugal, by monotypy. This species was figured by De Loriol (1900, p. 67, pl. 6, figs. 6–8), some of whose figures were copied by Mortensen (1948, p. 251, figs. 237a–d). These show it to be rather small, circular in outline, somewhat tumid above, flat or concave below, with equal, open petals, equilateral peristome, prominent bourrelets, and a terminal, longitudinally elongated periproct.

Lambert and Thiéry reduce *Lefortia* to a subgenus under *Procassidulus* (type species *Echinites lapis cancri* Leske), which, however, has a deeply sunken, supra-marginal periproct. The most conspicuous difference between *Lefortia* and *Faujasia* is the direction of elonga-

tion of the periproct—longitudinal in the first, transverse in the second. Though this might seem to be a very minor characteristic, it appears to have some importance in classification. Moreover, the periproct is commonly tilted downward in *Faujasia*, as in *Echinolampas*, whereas in *Lefortia* it is probably always vertical.

Lefortia is somewhat similar to *Ecanthus* Cooke (1942, p. 37) (= *Echinanthus* Desor 1858, not Leske 1778), but that genus has a transversely elongated peristome with rather small bourrelets, like *Cassidulus*, whereas *Lefortia* has an equilateral peristome and prominent bourrelets, somewhat resembling *Hardouinia*.

Lefortia trojana Cooke, n. sp.

Plate 4, figures 8–10

Test small; upper surface inflated, highest point well forward, sloping steeply forward and more gradually backward; lower surface flat or slightly concave; horizontal outline nearly circular. Apical system in front of the center but behind the highest point, monobasal (plates fused), with four genital pores; petals narrowly lanceolate, fairly long, poriferous zones open at both ends, pores conjugate, outer pores elongated, inner pores round. Peristome and surrounding region unknown. Periproct terminal, depressed, longitudinally elongated. Upper surface covered with small tubercles; tubercles near margin of lower surface much larger.

Length 20.5 mm; width 19.8 mm; height 13 mm.

Occurrence.—Mississippi: SW 1/4 sec. 15, T 11 S., R 4 E., 0.4 mile east of Troy, Pontotoc County, (U.S.G.S. 17259, Watson H. Monroe).

Geologic horizon.—Ripley formation, of middle Maestrichtian age.

Type.—U.S.N.M. 108376.

Remarks.—This species is represented by only one individual, which is somewhat crushed, and which has lost most of the lower side. It is the first of its genus known from the Americas. It resembles the figures of *Lefortia delgadoi* (De Loriol), but its profile is less symmetrical and its apex is higher. It can be distinguished from species of *Faujasia* by the direction of elongation of its periproct; moreover its petals are straighter and more widely open.

Genus PHYLLOBRISUS Cotteau

Phyllobrissus Cotteau, 1860, Soc. des Sciences hist. et nat. de l'Yonne Bull., tome 13, p. 434.

Phyllobrissus Cotteau. De Loriol, 1873, Échinologie helvétique, pt. 2, Échinides de la période crétacée, p. 233.

Phyllobrissus Cotteau. Cotteau, 1873, Paléontologie française, Terrain jurassique, ser. 1, tome 9, p. 320.

Phyllobrissus Cotteau. Pomel, 1883, Classification méthodique et genera des échinides, p. 60.

Phyllobrissus (*Anthobrissus*) Pomel, 1883, Classification méthodique et genera des échinides, p. 60. Type species *Nucleolites cerceleti* Desor, 1847, here designated.

Phyllobrissus (*Trochalia*) Pomel, 1883, Classification méthodique et genera des échinides, p. 60. Type species *Echinobrissus requienii* d'Orbigny = *Nucleolites requienii* Desor 1847. Not *Trochalia* Sharpe, 1850.

Asterobrissus De Loriol, 1888, Archiv Sci. phys. nat., ser. 3, tome 19, p. 71 (for *Trochalia* Pomel 1883 not Sharpe 1850).

Asterobrissus De Loriol. De Loriol, 1888, Soc. de physique et d'histoire nat. de Genève Mém., tome 30, no. 2, p. 104.

Phyllobrissus Cotteau. Duncan, 1889, Linnean Soc. London Jour., Zoology, vol. 23, p. 187.

Phyllobrissus Cotteau. Savin, 1903, Soc. hist. nat. Savoie Bull., ser. 2, tome 8, p. 130.

Phyllobrissus Cotteau. Lambert and Thiéry, 1921, Nomenclature raisonnée des échinides, fasc. 5, p. 350.

Asterobrissus De Loriol. Lambert and Thiéry, 1921, Nomenclature raisonnée des échinides, fasc. 5, p. 351.

Phyllobrissus Cotteau. Smiser, 1935, Mus. royal d'histoire nat. Mem., No. 68, p. 52.

Phyllobrissus Cotteau. Mortensen, 1948, Monograph of the Echinoidea, vol. 4, pt. 1, p. 165.

Asterobrissus De Loriol. Mortensen, 1948, Monograph of the Echinoidea, vol. 4, pt. 1, p. 167.

Type species *Catopygus gresslyi* L. Agassiz (1839) designated by Savin (1903). As figured by D'Orbigny (1854–1860, p. 425, pl. 966, figs. 1–6) this species has fairly long open petals, a pentagonal peristome surrounded by a distinct floscelle, and a supramarginal periproct sunken in a steep-walled sulcus, which slightly indents the margin. Its floscelle and nearly flush periproct distinguish *Phyllobrissus* from *Nucleopygus*. These features and its shorter sulcus distinguish it from *Nucleolites*. It differs from *Clypeopygus* in its smaller size and proportionally much greater height.

Phyllobrissus cubensis (Weisbord)

Plate 5, figures 11–14

Echinobrissus cubensis Weisbord, 1934, Bull. Am. Paleontology, vol. 20, no. 700, p. 191, pl. 21, figs. 1–3.

?*Petalobrissus burckhardti* Lambert, 1936, Soc. géol. France Bull., ser. 5, tome 6, p. 5, pl. 1, figs. 7, 8.

Nucleolites wilderae Ikins, 1940, Bull. Am. Paleontology, vol. 25, no. 90, p. 76, pl. 6, figs. 5a–c.

Echinobrissus cubensis Weisbord. Sanchez Roig, 1949, Equinodermos fósiles de Cuba, p. 127.

Horizontal outline ovate, slightly wider behind; upper surface moderately inflated, somewhat flattened behind; lower surface concave around the peristome; margin broadly rounded. Apical system in front of the center; four genital pores; large central madreporite. Ambulacra petaloid, petals rather short, extending halfway to the margin, poriferous zones narrower than the interporiferous zones, slightly open distally. Peristome excentric in front, pentagonal, surrounded by a weak floscelle. Periproct longer than wide, nearly midway between the margin and the apex, at the end of a furrow, which extends to the margin but does not indent it. Tubercles close together, in pits, larger on the lower surface, covering all the surface, very fine on the sternal band.

Length of figured specimen 29.4 mm; width 25 mm; height 14 mm.

Occurrence.—Cuba: Esperanza, Havana Province (type, *vide* Weisbord). Finca El Alambique Abreus, Santa Clara (*vide* Sanchez Roig).

Texas: Northeast of Castroville (U.S.G.S. 22407, William T. Watkins). Left bank Sabinal Creek about 4 miles north of Sabinal, Uvalde County (U.S.G.S. 7705, L. W. Stephenson). Sabinal Creek a few hundred yards below the G. H. & S. A. Ry. bridge about 1 mile west of Sabinal (U.S.G.S. 7709, 7710, L. W. Stephenson). Nueces River, left bank, 0.3 mile above the Southern Pacific Railway bridge, Uvalde County (U.S.G.S. 15340, 16152, L. W. Stephenson, S. F. Turner, and A. N. Sayre). Turkey Creek Bluff, Lithocarbon (Carbonville), (U.S.G.S. 1771, T. W. Vaughan). T. Corbur Asphalt Company mine 17 miles west of Uvalde (358, R. T. Hill). Southeast-facing slope of Anacacho Mountain overlooking Frypan Valley in Kinney County, about 5 miles southwest of Cline Station (U.S.G.S. 7719, L. W. Stephenson). Rio Seco, Medina County. Travis Heights, Austin (type of *Nucleolites wilderae*, F. L. Whitney).

Mexico: Ocozocoantla, Chiapas (*vide* Lambert, Frederico Mullerried, collector).

Geologic horizon.—Anacacho limestone and Austin chalk (type of *N. wilderae*) in Texas, lower Senonian in Mexico.

Type.—Paleontological Research Institution, Ithaca, N. Y.

Figured specimens.—U.S.N.M. 108380.

Remarks.—The type of *Nucleolites wilderae* Ikens, which was kindly loaned by Prof. F. L. Whitney, agrees in all recognizable characters with specimens in the National Museum from the Anacacho limestone. Though it is deeply corroded, it retains the petals. Its horizon, the Austin chalk, is lower than that of the Anacacho limestone.

Genus CLARKIELLA Lambert

Clarkiella Lambert, 1916, Revue critique de paléozoologie, tome 20, p. 169.

Cossmannaster Lambert, 1920, Revue critique de paléozoologie, tome 24, p. 138.

Cossmannaster Lambert. Lambert and Thiéry, 1921, Nomenclature raisonnée des échinides, fasc. 5, p. 369.

Cossmannaster Lambert. Mortensen, 1948, Monograph of the Echinoidea, vol. 4, pt. 1, p. 188.

Type species *Cassidulus conoideus* Clark=*Clarkiella hemispherica* (Slocum), by monotypy.

Lambert in 1920, overlooking the *i*, supposed that *Clarkiella* Lambert 1916 was preoccupied by *Clarkella* Walcott 1908; he proposed *Cossmannaster* as a substitute.

The only known species of this genus is represented by very tall, dome-shaped forms resembling *Conulus* in shape but differing from it in other features. The apical system and petals are like those of *Hardouinia*, though the petals are wider open than customary. The peristome is farther forward than that of *Hardouinia mortonis*, which is central. The floscelle appears to be similar, though the prominent bourrelets are so badly broken that one can only surmise their original shape. The periproct, which is taller than wide, is less deeply sunken than that of known species of *Hardouinia*. The shape and arrangement of the ambulacral and interambulacral plates resemble *Hardouinia*. *Clarkiella*

may prove to be either a synonym or a subgenus of *Hardouinia*.

Clarkiella hemispherica (Slocum)

Plate 5, figures 15–18

Cassidulus hemisphericus Slocum, 1909, Field Mus. Nat. History, Geol. Ser., vol. 4, p. 7, pl. 1, figs. 7–9.

Cassidulus hemisphericus (Slocum). Clark, 1915, U. S. Geol. Survey Mon. 54, p. 80, pl. 34, figs. 2a–c.

Cassidulus conoideus Clark, 1915, U. S. Geol. Survey Mon. 54 p. 80, pl. 27, figs. 3a–d.

Clarkiella conoidea (Clark). Lambert, 1916, Revue critique de paléozoologie, tome 20, p. 169.

Cossmannaster conoideus (Clark). Lambert and Thiéry 1921, Nomenclature raisonnée des échinides, fasc. 5, p. 369.

Cossmannaster hemisphaericus (Slocum). Lambert and Thiéry, 1921, Nomenclature raisonnée des échinides, fasc. 5, p. 369.

Cossmannaster hemisphaericus (Slocum). Sanchez Roig, 1926, Equinodermos fósiles de Cuba, p. 73.

Cossmannaster conoideus (Clark). Mortensen, 1948, Monograph of the Echinoidea, vol. 4, pt. 1, p. 188, figs. 169 (after Clark).

Cossmannaster hemisphaericus (Slocum). Mortensen, 1948, Monograph of the Echinoidea, vol. 4, pt. 1, p. 188.

Cossmannaster hemisphaericus (Slocum). Sanchez Roig, 1949, Equinodermos fósiles de Cuba, p. 144.

Horizontal outline circular; upper surface highly inflated; lower surface nearly flat. Apical system central; containing four genital plates with a large central madreporite; genital pores between the petals. Ambulacra plainly petaloidal; petals extending half-way to the margin; poriferous zones closed at the apex, open distally; outer pores elongated, inner pores circular; phylloides equilateral, connected by a groove with the peristome. Peristome in front of the center. Bourrelets broken, evidently large and probably pointed, projecting diagonally outward. Entire surface covered with very fine tubercles or granules, which are larger on the lower surface. Periproct above the margin; higher than wide; sunken in a very shallow groove.

Length of the type of *Cassidulus conoideus* 31 mm; width 31.4 mm; height 28 mm.

Occurrence.—Mississippi: White gullies on the Patterson farm about 3 miles south of Pontotoc (type, *vide* Slocum).

Alabama: Near Youngblood, Pike County (Ala. Geol. Survey, C. A. Burke).

Georgia: The Narrows, Pataula Creek 2 miles above its mouth, Clay County (U.S.G.S. 5376, Otto Veatch, type of *Cassidulus conoideus*).

Cuba: Ciego de Avila (*vide* Sanchez Roig).

Geologic horizon.—Probably Prairie Bluff chalk in Mississippi, marine facies of Providence sand in Georgia, of late Maestrichtian age.

Types.—Chicago Museum of Natural History, P. 10347, replicas in the U. S. National Museum. Type of *Cassidulus conoideus* U.S.N.M. 31199.

Remarks.—The preceding description is based on the type of *Cassidulus conoideus* which is much better preserved than that of *C. hemisphericus*. Clark was mistaken in supposing that it is a cast. Cleaning the specimen uncovered the test, which retains even the tubercles.

Genus **HARDOUINIA** Haime

- Hardouinia* Haime, in D'Archiac and Haime, 1853, Description des animaux fossiles de l'Inde, p. 214.
- Gonioclypeus* Emmons, 1858, North Carolina Geol. Survey Rept., Agriculture of the eastern counties, p. 309. Type species *G. subangulatus* Emmons = *H. mortonis* (Michelin).
- Echinanthus* Breynius (part). Desor, 1858, Synopsis des échinides fossiles, p. 295, note.
- Hardouinia* Haime, Pomel, 1883, Classification méthodique et genera des échinides, p. 65. (Typographical error for *Hardouinia*.)
- Echinanthus* (*Hardouinia*) Haime. Duncan, 1889, Linnean Soc. London Jour., Zoology, p. 183.
- Australanthus* Bittner, 1892, K. Akad. Wiss. Wien, vol. 101, pt. 1, p. 20. Type species *Cassidulus longianus* Gregory.
- Cassidulus* (*Hardouinia*) Haime. Gregory, 1892, Geol. Mag., decade 3, vol. 9, p. 436.
- Procassidulus* (*Hardouinia*) Haime. Lambert and Thiéry, 1921, Nomenclature raisonnée des échinides, fasc. 5, p. 362.
- Hardouinia* Haime. Cooke, 1942, Jour. Paleontology, vol. 16, no. 1, p. 6.
- Australanthus* Bittner. H. L. Clark, 1946, Carnegie Inst. Washington Pub. 566, p. 357.
- Hardouinia* Haime. Mortensen, 1948, Monograph of the Echinoidea, vol. 4, pt. 1, p. 137.
- Australanthus* Bittner. Mortensen, 1948, Monograph of the Echinoidea, vol. 4, pt. 1, p. 222.

Type species, *Pygorrhynchus mortonis* Michelin, by monotypy. Distinguishing features of this species, which is more fully described and figured herein, are its central, equilateral tubular peristome, its long, narrow, pointed, hollow toothlike bourrelets separated by deep pits, and its circular periproct, which is sunken in a tube that opens into a sulcus. Its four genital pores lie between the petals, and its central madreporite extends between the posterior oculars. Its conspicuous phylloides and toothlike bourrelets contrast sharply with the inconspicuous, unpitted phylloides and weak, rounded bourrelets of *Cassidulus caribaeorum* Lamarck, the type species of *Cassidulus*, whose peristome is transversely elongated and whose periproct, moreover, though roofed over by the test, is not tubular.

Cassidulus longianus Gregory (1890, p. 482, pl. 13, figs. 1-3), from Australia, the type species of *Australanthus*, resembles *Hardouinia mortonis* in many features, but its phylloides are narrower and have fewer pores. Its apical system is smaller, and its genital pores are closer together. Its periproct is longitudinally elongated, like that of several American species of *Hardouinia*.

Haime compares *Hardouinia* with *Pygurus*, but *P. montmollini* (Agassiz), the type species according to Mortensen, has longer, more open petals, and its periproct is submarginal.

Lambert and Thiéry (1909-1925, p. 362) classify *Hardouinia* as a subgenus under *Procassidulus* in spite of the fact that *Hardouinia* is the older name. *Procassidulus*, typified by *Echinites lapis cancri* Leske, is

elongated, and its peristome is excentric. Its apical system is similar to that of *H. mortonis*, and its peristomial region and periproct differ only in minor features. *P. lapis cancri* is much smaller than *H. mortonis*.

Key to the American species of *Hardouinia*

- Periproct circular, bourrelets narrow
 Test high----- *Hardouinia mortonis*
 Test low----- *Hardouinia mortonis emmonsii*
- Periproct oval or elongate
 Periproct plainly elongate, bourrelets wide
 Petals broad----- *Hardouinia kellumi*
 Petals narrow
 Test generally low, rounded----- *Hardouinia micrococcus*
 Test high, conical (Mexico)----- *Hardouinia potosiensis*
- Periproct oval
 Periproct not terminal, petals nearly closed
 Upper surface inflated
 Test not very small
 Margin broadly rounded, petals wide----- *Hardouinia bassleri*
 Margin acutely rounded, petals narrow
 Petals shorter----- *Hardouinia aequorea*
 Petals longer----- *Hardouinia florealis*
 Test small (Western Interior province)----- *Hardouinia stantoni*
 Upper surface very low (Western Interior province)----- *Hardouinia taylori*
 Periproct nearly terminal, posterior slope nearly vertical, petals plainly open----- *Hardouinia mcglameryae*

***Hardouinia mortonis* (Michelin)**

Plate 5, figures 19-21

- Pygorrhynchus mortonis* Michelin, 1850, Rev. et mag. zoologie, tome 2, p. 240.
- Hardouinia mortoni* (Michelin). Haime in D'Archiac and Haime, 1853, Description des animaux fossiles du groupe nummulitique de l'Inde, p. 214.
- Echinanthus mortonis* (Michelin). Desor, 1858, Synopsis des échinides fossiles, p. 295.
- Gonioclypeus subangulatus* Emmons, 1858, North Carolina Geol. Survey Report; Agriculture of the eastern counties, p. 309, figs. 242, 243.
- Cassidulus subquadratus* Conrad, 1860, Acad. Nat. Sci. Philadelphia Jour., ser. 2, vol. 4, p. 291, pl. 47, fig. 19.
- Cassidulus subconicus* Clark, 1891, Johns Hopkins Univ. Circ., vol. 10, no. 87, p. 76.
- Cassidulus subquadratus* Conrad. Clark, 1893, U. S. Geol. Survey Bull. 97, p. 70, pl. 31, figs. 1a-h.
- Cassidulus subconicus* Clark. Clark, 1893, Johns Hopkins Univ. Circ., vol. 12, no. 103, p. 52.
- Cassidulus subconicus* Clark. Clark, 1893, U. S. Geol. Survey Bull. 97, p. 71, pl. 32, figs. 1a-k.
- Cassidulus subquadratus* Conrad. Slocum, 1909, Field Mus. Nat. History Pub. 134, geol. ser., vol. 4, no. 1, p. 5.
- Cassidulus subquadratus* Conrad. Clark, 1915, U. S. Geol. Survey Mon. 54, p. 77, pl. 31, figs. 2a-g.

- Cassidulus subconicus* Clark. Clark, 1915, U. S. Geol. Survey Mon. 54, p. 77, pl. 32, figs. 1a-k.
- Echinanthus mortonis* (Michelin). Clark, 1915, U. S. Geol. Survey Mon. 54, p. 67.
- Cassidulus? subangulatus* (Emmons). Clark, 1915, U. S. Geol. Survey Mon. 54, p. 81.
- Proccassidulus (Hardouinia) mortoni* (Michelin). Lambert and Thiéry, 1921, Nomenclature raisonnée des échinides, fasc. 5, p. 362.
- Proccassidulus (Hardouinia) subconica* (Clark). Lambert and Thiéry, 1921, Nomenclature raisonnée des échinides, fasc. 5, p. 362.
- Hardouinia subquadrata* (Conrad). Stephenson and Monroe, 1940, Mississippi Geol. Survey Bull. 40, p. 278, pl. 9, figs. 1-3.
- Hardouinia mortoni* (Michelin). Mortensen, 1948, Monograph of the Echinoidea, vol. 4, pt. 1, p. 137, figs. 105, 107, 108 (after Clark, as *Cassidulus subquadratus*).

Test medium-sized to large, upper surface variably inflated, lower surface slightly concave, margin angular to acutely rounded, horizontal outline semi-circular in front, nearly straight posterolaterally, produced downward behind. Apical system having four genital pores located beyond the inner ends of the petals and outside of the large central madreporite, which extends between the posterior oculars. Petals lanceolate, extending more than halfway to the ambitus; poriferous zones closed at inner end, nearly closed and much wider at outer end; zygopores consisting of a circular inner pore conjugated with a slot-shaped outer pore of variable length. Peristome central, circular, tubular, surrounded by five strong, pointed hollow bourrelets covered with scalelike small tubercles and separated by deep pits. Phyllodes short, broad, depressed, very conspicuous. Periproct small, circular, located between the ends of the posterior petals, sunken in a conical tube that widens into a straight-sided sulcus, which extends to and slightly indents the ambitus. Upper surface covered with small sunken tubercles. Lower surface having a bare calluslike area extending backward from the floscelle; remainder covered with larger tubercles set at the outer edge of large semilunate scrobiculi.

Occurrence.—Mississippi: Near Pontotoc, Pontotoc County (type, *vide* Michelin); Tippah County (type of *Cassidulus subquadratus*, *vide* Conrad); Dumas, Tippah County (type of *Cassidulus subconicus*); Naber's farm at Dumas, sec. 23, T 5 S, R 4 E (U.S.G.S. 710, T. W. Stanton); NW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 16, T 10 S, R 3 E, 450 feet southeast of State Highway 15 at Chiwapa Creek, 2.1 miles south of Pontotoc courthouse (U.S.G.S. 17256, W. H. Monroe); Lander's mill on Cane Creek 9 miles south of Ripley, Tippah County (U.S.G.S. 714, T. W. Stanton). SE $\frac{1}{4}$ sec. 16, T 3 S, R 4 E, south-facing slope of Walnut Creek valley north of house of L. T. Braddock, Tippah County, (U.S.G.S. 17799, L. W. Stephenson and W. H. Monroe).

Alabama: Bluff on right bank of Chattahoochee River near old Alexander Landing, NW $\frac{1}{4}$ sec. 9, T 9 N, R 29 E, Barbour County (U.S.G.S. 858, 17959, 19068, 21166, T. W. Stanton, L. W. Stephenson, C. W. Cooke, J. Fred Hunter, W. H. Monroe, D. H. Eargle).

Georgia: Chattahoochee River 1 mile below the mouth of Pataula Creek, (U.S.G.S. 859, T. W. Stanton); Well at Bainbridge (U.S.N.M. 31904).

South Carolina: Myrtle Beach, cast up by the waves (U.S.G.S. 16435, W. F. Prouty, D. F. Hewett).

North Carolina: Wadsworth marl pit, Craven County (type of *Gonioclypeus subangulatus*, *vide* Emmons).

Atlantic Ocean: Georges Bank (type of *H. stetsoni*, *vide* Stephenson).

Geologic horizon.—Lower part of *Exogyra costata* zone; Ripley formation (Mississippi, Alabama), Peedee formation (South Carolina), of middle Maestrichtian age.

Type.—45, Verneuil collection (*vide* Desor). The type of *Gonioclypeus subangulatus* is U.S.N.M. 108381, deposited by Williams College. The type of *Cassidulus subquadratus* is Acad. Nat. Sci. Philadelphia 1492; there is a replica in the U. S. National Museum. The type of *Cassidulus subconicus* is U.S.N.M. 20264. The type of *Cassidulus emmonsi* is U.S.N.M. 73423. The type of *Hardouinia stetsoni* is Museum Comparative Zoology 3516.

Remarks.—Like most cassiduloids, there is a considerable range of variation in the shape of the upper surface of *Hardouinia mortonis*. Most individuals are rather high and evenly inflated. Extreme forms are the conical variety called *Cassidulus subconicus* by Clark and the much lower variety called *Cassidulus emmonsi* by Stephenson. The horizontal outline is rather uniform, and there is little variation in the oral side. The type of *Hardouinia stetsoni*, which I have not seen, is said to have fewer tubercles than that of *C. emmonsi*.

Hardouinia mortonis emmonsi (Stephenson)

Plate 5, figures 22-24

?*Cassidulus berryi* Twitchell, 1915, U. S. Geol. Survey Mon 54, p. 220, pl. 101, figs. 3a-d.

?*Hardouinia berryi* (Twitchell). Lambert and Thiéry, 1921, Nomenclature raisonnée des échinides, fasc. 5, p. 363.

Cassidulus emmonsi Stephenson, 1927, U. S. Natl. Mus. Proc., vol. 47, art. 10 (no. 2706), p. 7, pl. 3, figs. 3-8; pl. 4, figs. 1-5.

Hardouinia? stetsoni Stephenson, 1936, Geol. Soc. America Bull., vol. 47, no. 3, p. 371, pl. 1, figs. 2-4.

Differs from typical *Hardouinia mortonis* in its smaller size and lower, more conical form. According to Stephenson *H. stetsoni* differs from *H. emmonsi* only in its coarser, sparser tuberculation.

Length of holotype of *H. emmonsi* 40 mm; width 38.5 mm; height 19.7 mm.

Occurrence.—North Carolina: Niells Eddy Landing, Cape Fear River 28 miles above Wilmington (U.S.N.M. 103700, type of *Cassidulus berryi*, E. W. Berry). New Rocky Point quarry, 1 mile northeast of Rocky Point station, Pender County (U.S.G.S. 12262, type of *H. emmonsi*, L. B. Kellum; U.S.G.S. 13585, paratypes, L. W. Stephenson). Cape Fear River 15.5 miles above Wilmington (U.S.G.S. 4151, L. W. Stephenson). Well at waterworks, Wilmington (U.S.N.M. 28930, paratype, J. A. Holmes). Quarry 1 mile west of Castle Hayne (U.S.G.S. 14524, W. C. Mansfield).

Georgia: Well at Bainbridge (U.S.N.M. 31904).

Texas: Indio Ranch, about 18 miles by road (15 miles airline) below Indio Ranch headquarters and about 0.5 mile from the Rio Grande, Maverick County (U.S.G.S. 10854, L. W. Stephenson). Uvalde County 1.4 miles southeast of old Widow Cook Ranch, 0.8 mile due east of Nueces River (U.S.G.S. 15350,

L. W. Stephenson). Uvalde County, west slope of a mesa 1 mile north of Pulliam Ranch House (U.S.G.S. 15378, Julia Gardner).

Atlantic Ocean: Georges Bank (type of *H. stetsoni*).

Geologic horizon.—Upper part of the *Exogyra costata* zone; upper part of Peedee formation in North Carolina, top of Escondido formation in Texas.

Types.—Type of *C. emmonsii*, U.S.N.M. 73423; paratypes, 73424, 28930. Type of *H. stetsoni*, Museum of Comparative Zoology 3516, Harvard University, Cambridge, Mass.

Remarks.—The specimens from Texas are uniformly smaller than the types of *H. emmonsii* from North Carolina. An average-sized specimen from the Indio Ranch measures 26 by 24 by 10.6 mm. The type of *Cassidulus berryi* is small, corroded, too badly preserved to be certainly recognizable. It was found in the Pliocene Waccamaw formation, evidently reworked from the underlying Peedee formation.

Hardouinia kellumi (Stephenson)

Plate 7, figures 1–5

Cassidulus kellumi Stephenson, 1927, U. S. Natl. Mus. Proc. no. 2706, vol. 72, art. 10 (no. 2706), p. 5, pl. 1, figs. 1–6; pl. 2, figs. 1–4; pl. 3, figs. 1, 2.

Horizontal outline nearly circular, slightly protracted behind; upper surface hemispherical; lower surface nearly flat; margin acutely rounded. Apical system central, having four genital pores located between the ends of the petals; madreporite central and protruding between the posterior oculars. Petals broadly lanceolate, closed at the inner ends, slightly open at the outer ends, extending more than halfway to the margin. Peristome central, surrounded by five strong, pointed deltoid phyllodes, which, when unworn, nearly close the opening. Floscelles conspicuous, fan-shaped, not deeply pitted. Periproct longitudinally elongated, supramarginal, sunken in a deep, narrow sulcus, which broadens and becomes shallow near the ambitus.

Length of holotype 57.3 mm; width 53.3 mm; height 31.3 mm.

Occurrence.—North Carolina: Rock Point quarries 1 mile northeast of Rocky Point station, Pender County (U.S.G.S. 12262, type, L. B. Kellum; U.S.G.S. 13585, L. W. Stephenson).

Geologic horizon.—Upper part of Peedee formation, upper part of *Exogyra costata* zone, of middle Maestrichtian age.

Type.—U.S.N.M. 73420; paratypes, 73421.

Comparisons.—*Hardouinia kellumi* seems to be closely related to *H. micrococcus* (Gabb), but that species is proportionately narrower, much flatter, and has narrower petals, which are wider open.

Hardouinia potosiensis Lambert (1936, p. 5, pl. 1, figs. 2–4) from the Santonian of San Luis Potosí, Mexico, is more elongated and has narrower petals.

Hardouinia micrococcus (Gabb)

Plate 6, figures 1–10; plate 7, figure 12

Cassidulus micrococcus Gabb, 1860, Acad. Nat. Sci. Philadelphia Proc., vol. 12, p. 519.

?*Cassidulus abruptus* Conrad, 1860, Acad. Nat. Sci. Philadelphia Jour., ser. 2, vol. 4, p. 291.

Cassidulus micrococcus Gabb. Clark, 1891, Johns Hopkins Univ. Circ., vol. 10, no. 87, p. 76.

Cassidulus porrectus Clark, 1891, Johns Hopkins Univ. Circ., vol. 10, no. 87, p. 76.

Cassidulus micrococcus Gabb. Clark, 1893, Johns Hopkins Univ. Circ., vol. 12, no. 103, p. 52.

Cassidulus porrectus Clark. Clark, 1893, Johns Hopkins Univ. Circ., vol. 12, no. 103, p. 52.

Cassidulus micrococcus Gabb. Clark, 1893, U. S. Geol. Survey Bull. 97, p. 69, pl. 30, figs. 1a–i.

Cassidulus porrectus Clark. Clark, 1893, U. S. Geol. Survey Bull. 97, p. 72, pl. 33, figs. 1a–b; pl. 35, figs. 1a–d.

?*Cassidulus abruptus* Conrad. Clark, 1893, U. S. Geol. Survey Bull. 97, p. 92.

Cassidulus micrococcus Gabb. Clark, 1915, U. S. Geol. Survey Mon. 54, p. 76, pl. 31, figs. 1a–i.

Cassidulus porrectus Clark. Clark, 1915, U. S. Geol. Survey Mon. 54, p. 78, pl. 32, figs. 2a–b; pl. 33, figs. 1a–f.

?*Cassidulus abruptus* Conrad. Clark, 1915, U. S. Geol. Survey Mon. 54, p. 81.

Hardouinia porrecta (Clark). Lambert and Thiéry, 1921, Nomenclature raisonnée des échinides, fasc. 5, p. 362.

Hardouinia porrecta (Clark). Stephenson and Monroe, 1940, Mississippi Geol. Survey Bull. 40, table facing p. 248, pl. 8 (p. 277), figs. 1, 2.

Hardouinia porrecta (Clark). Mortensen, 1948, Monograph of the Echinoidea, vol. 4, pt. 1, p. 138, fig. 106 (after Clark).

Test large, ranging in length from 40 mm to 125 mm; horizontal outline ovate, slightly produced behind, wider behind the midline; upper surface convex, height less than half the length; oral surface nearly flat. Apical system slightly in front of the center; four genital pores between the ends of the petals; madreporite large, central and extending between the posterior ocular plates. Ambulacra plainly petaloid; petals all alike, of equal length, extending about three-fourths of the distance to the margin, subspatulate; poriferous zones open at each end, inner pores circular, outer pores elongate, pores conjugate; interporiferous zones twice as wide as the poriferous. Peristome small, pentagonal, central, surrounded by five strong, pointed, deltoid, toothlike bourrelets separated by narrow deep grooves; phyllodes fanlike, wider than long, limited by lateral arcs of 10 pores each and a median arc of about six pores. Periproct elongate oval, at the bottom of a deep groove, which widens and becomes shallower toward the margin. Tubercles on oral surface having a scalelike appearance.

Length of figured type 44.2 mm; width 39 mm; height 19.5 mm. Length of type of *C. porrectus* 109 mm; width 104 mm; height 45 mm.

Occurrence.—Alabama: Eufaula (type, W. M. Gabb). Barbour County (figured, Geol. Survey Ala., Michael Tuomey). Bluff, Chattahoochee River (Geol. Survey Ala., E. A. Smith). Bluff on right bank of Chattahoochee River near old Alexander Landing, NW $\frac{1}{4}$ sec. 9, T 9 N., R 29 E, $8\frac{3}{4}$ miles below Eufaula (U.S.G.S. 858, type of *C. porrectus*, T. W. Stanton; U.S.G.S. 17859, C. W. Cooke and J. F. Hunter; U.S.G.S. 19068, L. W. Stephenson, C. W. Cooke, and W. H. Monroe). Chewalla Creek near Eufaula (U.S.G.S. 279, Frank Burns).

Georgia: Chattahoochee River 1 mile below the mouth of Pataula Creek (U.S.G.S. 859, T. W. Stanton). Two miles north of Pataula Creek, Clay County.

Geologic horizon.—Ripley formation, of middle Maestrichtian age.

Types.—Academy of Natural Sciences of Philadelphia no. 1480. Type of *C. porrectus* U.S.N.M. 21890.

Comparisons.—This species attained a much larger size than *Hardouinia mortonis*. It is proportionately lower; its bourrelets are much wider, and the spaces between them are correspondingly narrower; its periproct is longer, and the furrow into which it opens is more expanding. It appears to be more closely related to *Hardouinia kellumi*, which has similar bourrelets though its anal groove is wider, its petals are much narrower, and its height is proportionately less.

Gabb's two types are small and decorticated, but there is little reason to doubt that they represent the same species as the big, overgrown lot from which Clark selected the type of *Cassidulus porrectus*. All came from the same region and probably from the same horizon.

Hardouinia micrococcus is generally lower and more evenly rounded than the figures of *Hardouinia potosiensis* Lambert (1936, p. 5, pl. 1, figs. 2-4) from the Santonian of Mexico, though some large individuals (*H. porrectus*) are asymmetrically conical like it.

Hardouinia bassleri (Twitchell)

Plate 7, figures 6-11

Cassidulus bassleri Twitchell, 1915, U. S. Geol. Survey Mon. 54, p. 211, pl. 95, figs. 5a-d.

Procassidulus (*Hardouinia*) *bassleri* (Twitchell). Lambert and Thiéry, 1921, Nomenclature raisonnée des échinides, fasc. 5, p. 363.

Test rather small; horizontal outline rounded in front and sides, somewhat flattened posterolaterally; upper surface low convex, arched above the periproct; lower surface gently concave; margin broadly rounded. Apical system central or slightly in front of the center; four genital pores; madreporite central. Ambulacra petaloid; petals lanceolate, extending about three-fourths the way to the margin; poriferous zones closed at the apex, nearly closed distally; pores oval, conjugate. Peristome commonly a little behind the center. Phyllodes limited on each side by a curved line of about 11 close-set small pores, and there are two inner nearly straight widely separated lines of about 6 pores; not distinctly pitted; sloping steeply near the peristome. Bourrelets conspicuous, blunt, hollow. Periproct oval,

erect, in a shallow tube that opens into a rounded sulcus, located between the tips of the posterior petals.

Length of an average specimen 30 mm; width 28 mm; height 16 mm.

Occurrence.—Alabama: Cunninghams Bluff, Alabama River, Dallas County, frac. sec. 3 and 4, T 16 N, R 12 E (U.S.G.S. 175, L. C. Johnson). Morgan Landing, J. T. Wood's place, secs. 11 and 12, T 17 N, R 12 E, Autauga County (U.S.G.S. 307, L. C. Johnson). Bluff on Valley Creek 100 yards above the crossing of U. S. Highway 80, Dallas County (U.S.G.S. 16997, L. W. Stephenson and A. C. Munyan). Batte Smith Bluff on Alabama River, Dallas County (D. H. Eargle). Catoma Creek, Montgomery County, 0.9 mile northeast of the Mount Moriah Church, 0.15 mile northwest of the old Haynesville road, in NW $\frac{1}{4}$ sec. 32, T 16 N, R 17 E (U.S.G.S. 17010, L. W. Stephenson, C. W. Cooke, and A. C. Munyan; W. H. Monroe and D. H. Eargle).

Geologic horizon.—Tombigbee sand member of the Eutaw formation, of Santonian (?) age.

Type.—U.S.N.M. 9476.

Figured specimens.—U.S.N.M. 108382.

Comparisons.—Of American species *Hardouinia bassleri* most closely resembles *Hardouinia aequorea* (Morton), which commonly has a sharper margin, is more concave underneath, and has closer inner rows of pores on its phyllodes.

This species was referred to *Procassidulus* by Lambert and Thiéry, but *Procassidulus lapis caneri* (Leske), the type species, has a perfectly flat oral face, its margin is sharp, and its peristome is farther forward.

The original label of the type lot of *Cassidulus bassleri* Twitchell was lost. The lot was relabelled by Angelo Heilprin as from the Miocene of North Carolina, evidently a mistake. The state of preservation and the matrix resemble specimens collected in 1883 by L. C. Johnson at Cunningham Bluff, Alabama River (U.S.G.S. 175).

Hardouinia aequorea (Morton)

Plate 8, figures 15-22

Cassidulus aequoreus Morton, 1834, Synopsis of the organic remains of the Cretaceous, p. 76, pl. 3, fig. 14.

Cassidulus aequoreus Morton. D'Orbigny, 1856, Paléontologie française, Terrain crétacé, ser. 1, tome 6, p. 329, pl. 926, figs. 6-12.

Cassidulus aequoreus Morton. Desor, 1858, Synopsis des échinides fossiles, p. 290.

Cassidulus aequoreus Morton. Clark, 1891, Johns Hopkins Univ. Circ., vol. 10, no. 87, p. 76.

Cassidulus aequoreus Morton. Clark, 1893, Johns Hopkins Univ. Circ., vol. 12, no. 103, p. 52.

Cassidulus aequoreus Morton. Clark, 1893, U. S. Geol. Survey Bull. 97, p. 68, pl. 29, figs. 1a-i.

Cassidulus aequoreus Morton. Weller, 1907, New Jersey Geol. Survey, Paleontology ser., vol. 4, p. 293, pl. 12, figs. 5-12 (after Clark, 1893).

Cassidulus intermedius Slocum, 1909, Field [Chicago] Mus. Nat. History, geol. serv. vol. 4, p. 6, pl. 1, figs. 1-6.

Cassidulus aequoreus Morton. Clark, 1915, U. S. Geol. Survey Mon. 54, p. 75, pl. 30, figs. 2a-i.

Cassidulus intermedius Slocum. Clark, 1915, U. S. Geol. Survey Mon. 54, p. 79, pl. 34, figs. 1a-f.

Test small; horizontal outline ovate, wider behind the middle, slightly produced posteriorly; upper surface

dome-shaped; lower surface concave; margin acutely rounded. Apical system in front of the center; four genital pores, the right posterior farther out than the others. Ambulacra petaloid, petals lanceolate, extending about three-fourths of the way to the margin, poriferous zones closed at the apex, somewhat open distally; inner pores circular, outer pores oval or elongate, pores conjugate; phyllodes outlined by arcs of six to eight large pores, arcs separated distally by four or five large pores and a median staggered row of very small pores; phyllodes separated from the peristome by a wide, deep granulated furrow. Bourrelets strong, bluntly pointed, not projecting across the peristome. Peristome pentagonal, somewhat sunken. Periproct longer than wide, sunken in a groove, which extends to the margin but does not indent it; lying between the ends of the posterior petals. Sternal area and basal part of anterior ambulacrum decorated with very small tubercles; remainder of lower surface covered with much larger tubercles in sunken scrobiculi; tubercles on upper surface medium-sized.

Length of type 28 mm; width 25 mm; height 11.5 mm.

Length of figured specimen 32 mm; width 28 mm; height 15.5 mm.

Occurrence.—Alabama: Prairie Bluff, Alabama River, Wilcox County (type, S. G. Morton; U.S.G.S. 6793, L. W. Stephenson). Old Canton Landing, Alabama River about 14 miles below the mouth of Pine Barren Creek, Wilcox County (U.S.G.S. 6439, L. W. Stephenson). Shell Bluff, Prairie Creek (U.S.G.S. 6794, L. W. Stephenson).

Mississippi: Gully on campus east of buildings of A. & M. College near Starkville, Oktibbeha County (U.S.G.S. 6843, W. N. Logan).

Geologic horizon.—Prairie Bluff chalk, of late Maestrichtian age.

Type.—Acad. Nat. Sci. Philadelphia 1475. Type of *Cassidulus intermedius* Chicago Nat. History Mus. no. P10346; replicas in U. S. National Museum.

Figured specimen.—U.S.N.M. 108383, from U.S.G.S. 6794.

Comparisons.—*Hardouinia aequorea* appears to have somewhat shorter petals than *H. florealis*. It has shorter petals than *H. bassleri*, its apical system and peristome are farther forward, its periproct is more elongated, and its margin is more acute. It shows some similarity to *Procassidulus lapis cancri* (Leske), but that species has a perfectly flat oral face, and its peristome is farther forward.

Hardouinia florealis (Morton)

Plate 8, figures 11–14

Clypeaster florealis Morton, 1833, Am. Jour. Sci., ser. 1, vol. 23, p. 294.

Clypeaster florealis Morton. Morton, 1834, Synopsis of the organic remains of the Cretaceous group, p. 76, pl. 3, fig. 12; pl. 10, fig. 12.

Pygurus florealis (Morton). Agassiz and Desor, 1847, Catalogue raisonné des échinodermes, p. 141.

Faujasia florealis (Morton). D'Orbigny, 1856, Paléontologie française, Terrain crétacé, ser. 1, tome 6, p. 319, pl. 920, figs. 5, 6 (after Morton).

Faujasia florealis (Morton). Desor, 1858, Synopsis des échinides fossiles, p. 318.

Cassidulus florealis (Morton). Meek, 1864, Smithsonian Misc. Coll., vol. 7, (177), p. 2.

Cassidulus florealis (Morton). Clark, 1891, Johns Hopkins Univ. Circ., vol. 10, no. 87, p. 76.

Cassidulus florealis (Morton). Clark 1893, Johns Hopkins Univ. Circ., vol. 12, no. 103, p. 52.

Cassidulus florealis (Morton). Clark, 1893, U. S. Geol. Survey Bull. 97, p. 66, pl. 28, figs. 1a–l.

Cassidulus florealis (Morton). Clark, 1915, U. S. Geol. Survey Mon. 54, p. 74, pl. 30, figs. 1a–l.

Procassidulus florealis (Morton). Lambert and Thiéry, 1921, Nomenclature raisonnée des échinides, fasc. 5, 361.

Faujasia florealis (Morton). Lambert and Thiéry, 1921, Nomenclature raisonnée des échinides, fasc. 5, p. 374.

Horizontal outline subcircular; upper surface strongly inflated; highest point behind the apical system; lower surface flat or slightly concave; margin acute. Petals extending more than halfway to the margin; poriferous zones about as wide as the interporiferous. Peristome central; surrounded by five strong, pointed, hollow bourrelets; phyllodes longer than wide. Periproct oval, twice as high as wide, sunken, well up above the margin, opening into a shallow depression, which extends to the margin.

Length 38.1 mm; width 34.1 mm; height 21.2 mm.

Occurrence.—Delaware and Chesapeake Canal, Delaware.

Geological horizon.—Upper Cretaceous; formation unknown, probably the Marshalltown formation.

Type.—Acad. Nat. Sci. Philadelphia 1495.

Comparisons.—*Hardouinia florealis*, known only from internal molds, differs from *Hardouinia mortonis* (Michelin), type of the genus, in the shape of its periproct, which is longitudinally elongated, not circular, and in the narrowness of its interporiferous zones. Its recognizable features closely resemble a tall variety of *Hardouinia aequorea* (Morton), though the type of that species is much lower, its phyllodes are shorter, and its petals are somewhat shorter. The shape of its periproct allies *Hardouinia florealis* with *H. micrococcus* (Gabb), but that species is very much flatter, and its floscelle is smaller.

Hardouinia stantoni (Clark)

Plate 8, figures 7–10

Cassidulus stantoni Clark, 1891, Johns Hopkins Univ. Circ., vol. 10, no. 87, p. 76.

Cassidulus stantoni Clark. Clark, 1893, Johns Hopkins Univ. Circ., vol. 12, no. 103, p. 52.

Cassidulus stantoni Clark. Clark, 1893, U. S. Geol. Survey Bull. 97, p. 73, pl. 35, figs. 2a–d.

Cassidulus stantoni Clark. Clark 1915, U. S. Geol. Survey Mon. 54, p. 79, pl. 33, figs. 2a–d.

Procassidulus stantoni (Clark). Lambert and Thiéry, 1921, Nomenclature raisonnée des échinides, fasc. 5, p. 361.

Test small. Horizontal outline oval; upper surface dome-shaped; lower surface concave; margin acutely rounded; slightly produced behind. Apical system wanting. Ambulacra plainly petaloidal; petals extending about halfway to the margin; poriferous zones somewhat wider than the interporiferous, open distally;

inner pores circular, outer pores elongated; pores conjugate. Phyllodes longer than wide; bordered by open arcs of many small, closely spaced pores; inner pores small, close together, arranged in two lines that divide the phyllode into three equal areas. Peristome central, pentagonal. Bourrelets fairly strong, rounded, not projecting far across the peristome. Periproct nearly midway between the margin and the apex; higher than wide; sunken in a tube that opens into a sulcus. Tubercles small; larger on the lower surface; scrobiculated.

Length 15 mm; width 13.7 mm; height 8.7 mm.

Occurrence.—Colorado: One mile east of Quillian's ranch on Williams Creek, Huerfano County, (type, U.S.G.S. 743, T. W. Stanton). Muddy Creek, Huerfano County, (U.S.N.M. 20267, T. W. Stanton).

Geologic horizon.—Codell sandstone member of the Carlile shale, same age as uppermost part of the Eagle Ford shale (Turonian).

Type.—U.S.N.M. 20268.

Comparisons.—This species resembles in shape *Hardouinia aequorea* (Morton), but the type is much smaller and has much shorter petals. It is higher than *Hardouinia taylori* (Warren), and its periproct is smaller.

Hardouinia taylori (Warren)

Plate 8, figures 1-6

Cassidulus taylori Warren, 1926, Royal Soc. Canada Trans., ser. 3, vol. 20, sec. 4, p. 11, pl. 1, figs. 10-13.

Test small; horizontal outline shield-shaped, with posterolateral truncations, produced behind; upper surface low-arched; oral surface concave. Apical system central, with four genital pores, the right posterior pore farther out than the others. Ambulacra petaloid; petals short, extending only halfway to the margin; narrow, open distally; pores round. Peristome central; bourrelets strong, protruding; phyllodes large, about as wide as long. Periproct large, round (?), about midway between the apex and the margin, opening into a shallow sulcus.

Length of cotype 301 18 mm; width 17.2 mm; height 6.1 mm.

Occurrence.—Canada: North end of the northeast arm of Birch Lake, Alberta, near Innisfree in sec. 1, T 51, R 12, west 4th Principal Meridian (type, P. S. Warren).

Colorado: Road from Meeker to Craig, 6 miles northeast of Meeker (U.S.G.S. 14699, I. A. Keyte).

Geologic horizon.—Birch Lake sandstone, Belly River series in Canada; in sandstone 200 feet below top of Mancos shale in Colorado; both of Campanian age.

Types.—University of Alberta 301-303, Edmonton.

Comparisons.—*Hardouinia taylori* is flatter than any other described species. Its margin is sharper than that of *H. stantoni*, which has a narrower periproct.

Hardouinia mcglameryae Cooke, n. sp.

Plate 8, figures 23-26

Horizontal outline ovate, somewhat wider behind than in front; upper surface strongly arched, oral sur-

face nearly flat; margin acutely rounded. Apical system in front of the center, with a tumid central madreporite which separates the posterior oculars; four genital pores. Petals spatulate, long, wide; poriferous zones open distally; inner pores oval, outer pores elongated, conjugate, plates diagonal; interporiferous zones twice as wide as poriferous. Peristome slightly anterior, sunken in a tube, surrounded by a conspicuous floscelle with strong, pointed, toothlike bourrelets. Periproct ovate, higher than wide, slightly sunken, high above the margin, opening into a shallow, nearly vertical groove, which extends to the margin. Tubercles scrobiculate, very small on upper surface, much larger on oral surface.

Length 36.8 mm; width 36.4 mm; height 24.7 mm.

Occurrence.—Alabama: Near Youngblood, Pike County (Alabama Geol. Survey, C. A. Burke).

Geologic horizon.—Probably Providence sand (the label says Ripley).

Type.—Geological Survey of Alabama; replica, U.S.N.M. 108384.

Comparisons.—The petals of *Hardouinia mcglameryae* closely resemble those of *Clarkiella hemispherica* (Slocum), but the periproct is much higher. The petals are wider open at the outer tips than those of *Hardouinia mortonis* (Michelin), and the posterior slope is much steeper, nearly vertical. The spaces between the bourrelets in *H. mcglameryae* slope steeply toward the peristome; the corresponding spaces in *H. mortonis* are separated from the peristome by thick walls.

Genus ECHINOCORYS Leske

Echinocorys Leske, 1778, Klein's Naturalis dispositio echinodermatum, p. 175.

Echinocorytes Leske, 1778, Klein's Naturalis dispositio echinodermatum, p. 176.

Ananchites Lamarck, 1801, Système des animaux sans vertèbres, p. 347.

Ananchyles (Lamarck). Lamarck, 1816, Histoire naturelle des animaux sans vertèbres, tome 3, p. 23.

Ananchytes Lamarck. Goldfuss, 1833, Petrefacta germanii, p. 144; 2d ed., 1862, p. 134.

Ananchytes Lamarck. Forbes, 1852, United Kingdom Geol. Survey Mem. British organic remains, decade 4, plate 6, p. 1.

Echinocorys Breynius. D'Orbigny, 1854, Paléontologie française, Terrain crétacé, ser. 1, tome 6, p. 58.

Ananchytes Lamarck. Desor, 1858, Synopsis des échinides fossiles, p. 329.

Echinocorys Breynius. Cotteau and Triger, 1869, Échinides du département de la Sarthe, p. 430.

Echinocorys Breynius. De Loriol, 1873, Échinologie helvétique, ser. 6, pt. 2, p. 307.

Echinocorys Breynius. Wright, 1882, Monograph of the British fossil Echinodermata from the Cretaceous formations, vol. 1, pt. 10, p. 327.

Ananchytes Lamarck. Pomel, 1883, Classification méthodique et genera des échinides, p. 47.

Echinocorys Breynius. Duncan, 1889, Linnean Soc. London Jour., Zoology, vol. 23, p. 206.

Echinocorys Breynius. Lambert, 1903, Mus. royal d'histoire nat. de Belgique Mém., tome 2, art. 4, p. 34.

Echinocorys Breynius. Savin, 1903, Soc. d'histoire naturelle de Savoie Bull., tome 8, p. 97.

Echinocorys Breynius. Lambert and Thiéry, 1924, Nomenclature raisonnée des échinides, fasc. 6, p. 417.

Echinocorys Breynius. Smiser, 1935, Mus. royal d'histoire nat. de Belgique Mém., no. 67, p. 9.

Echinocorys Breynius. Mortensen, 1950, Monograph of the Echinoidea, vol. 5, pt. 1, p. 64.

Type species *Echinocorys scutatus* Leske, by monotypy. This species, which is identified by Leske as Breyn's plate 3, figures 1, 2, was called *Echinocorys vulgaris* by D'Orbigny (1854-1860, p. 62, pls. 804-808), who attributed the name to Breyn, a pre-Linnaean author. D'Orbigny classed as synonyms Lamarck's *Ananchytes ovata*, *A. striata*, *A. gibba*, and *A. pustulosa*. He considered it the most characteristic species of the White Chalk (Senonian) of Europe. Smiser (1935, p. 50) restricts typical *E. "vulgaris"* to the lowermost Senonian (Coniacian) but recognized a variety, *striata*, in the basal Campanian and a great profusion of related species in the upper Senonian. According to Wright (1864-1882, p. 333) *Ananchytes striata* Lamarck and *Echinocorys scutatus* Leske are the same variety of *Echinocorys vulgaris*, a very variable species.

Echinocorys texanus (Cragin)

Plate 10, figures 1, 2; plate 11, figure 17

Ananchytes texana Cragin, 1893, Texas Geol. Survey Fourth Ann. Rept., p. 145, pl. 25, fig. 12; pl. 26, figs. 1, 2.

Ananchytes texana Cragin. Clark, 1915, U. S. Geol. Survey Mon. 54, p. 82, pl. 35, figs. 2a-c; pl. 36, figs. 1a-b.

Echinocorys texanus (Cragin). Adkins, 1928, Texas Univ. Bull. 2838, p. 286, pl. 37, figs. 5, 6.

Echinocorys cf. *E. texana* (Cragin). Dane, 1929, Arkansas Geol. Survey Bull. 1, p. 86, pl. 15, figs. 1, 2.

Test large; horizontal outline ovate; upper surface very much inflated, dome-shaped; oral surface nearly flat, concave around the peristome; margin acutely rounded. Apical system central, elongated; plates arranged in two parallel rows headed by the anterior ocular, which is much smaller than the other plates. Ambulacra narrow, subpetaloid; petals extending to margin, all alike, poriferous zones straight, pores oval, conjugate, pairs close together, one pair to each plate; pore pairs on oral surface very small and far apart, except around the peristome, where they form a floscelle; pores of each pair in floscelle separated by a large tubercle. Peristome transversely oval, at the anterior sixth. Periproct longitudinally oval, submarginal.

Length of figured specimen 122 mm; width 106 mm; height 93 mm.

Occurrence.—Texas: Seco Creek, 2½ miles northwest of D'Hanis, Medina County (type). Seco Creek southwest of old Rothe ranch house, about 3 miles north by west of D'Hanis (U.S.G.S. 12909, figured specimens, L. W. Stephenson). Seco Creek 1½ miles northwest of D'Hanis (U.S.G.S. 14707, N. H.

Darton). Seco Creek about 2 miles above the Galveston, Harrisburg, & San Antonio Railway bridge, Medina County (U.S.G.S. 7694, L. W. Stephenson). Eastern branch of Hendricks Creek, 1.1 miles southwest of Rogers, Bell County (U.S.G.S. 14611, L. W. Stephenson). Big Creek at road bridge just south of the McLennan-Falls County line, 4 miles north by west of Otto, Falls County (H. R. Blank). Kaufman County 2 miles from Forney (U.S.N.M. 22960, M. A. George). Southward-flowing creek 5.4 miles east of Clarksville, 200 yards below the Clarksville-Texarkana road, Red River County (U.S.G.S. 12888, L. W. Stephenson). Branch of Kickapoo Creek 6.5 miles east of Clarksville, 1 mile south of the Texarkana road (U.S.G.S. 13557, L. W. Stephenson and C. H. Dane). Same creek as preceding 1¼ miles south of the Texarkana road (U.S.G.S. 13558, L. W. Stephenson and C. H. Dane). Same, 1.5 miles south of Texarkana road (U.S.G.S. 13559, L. W. Stephenson and C. H. Dane). Branch of Kickapoo Creek, about 0.45 mile above iron bridge, 2.25 miles northwest of Annona, Red River County (U.S.G.S. 14077, L. W. Stephenson). Jakes Creek, 5 miles east of Clarksville, 0.2 mile below the Clarksville-Texarkana highway, Red River County (U.S.G.S. 14060, L. W. Stephenson). Jakes Creek, 3 miles south of Texarkana highway, 5 miles east of Clarksville (U.S.G.S. 14539, L. W. Stephenson, T. W. Stanton, and J. B. Reeside, Jr.). Creek near railroad, 4 miles east of Clarksville (U.S.G.S. 5437, C. H. Gordon). Youngs Creek, 0.8 mile south of Texarkana road, 4 miles east of Clarksville (U.S.G.S. 13085). Youngs Creek less than 1 mile north of T. & P. Railroad, 4 miles east of Clarksville (U.S.G.S. 13086). White Rock, Red River County (U.S.G.S. 13560, L. W. Stephenson).

Arkansas: White Cliffs, Sevier County (U.S.G.S. 7488, T. W. Stanton and L. W. Stephenson; U.S.G.S. 13092, L. W. Stephenson and W. C. Spooner; F. K. Bostwick). Rocky Comfort, 17 miles southwest of Foreman, Little River County (U.S.G.S. 13506, C. H. Dane); White Hill, 2.9 miles south of Rocky Comfort (U.S.G.S. 13507, C. H. Dane).

Geologic horizon.—Anacacho limestone in Medina County, Texas; Taylor marl, Pecan Gap chalk member in Bell County, Texas, Pecan Gap chalk member in Falls and Milam Counties, Texas; Annona chalk in Red River County, Texas and in Arkansas. All of Campanian (middle Senonian) age.

Type.—Texas Geological Survey (*vide* Clark); figured specimen, U.S.N.M. 108388.

Remarks.—*Echinocorys texanus* attained a much larger size than most specimens of *E. scutatus* Leske, the type of the genus. It differs from it further in that the petaliferous parts of the ambulacra extend about to the margin, whereas they commonly reach less than halfway to the margin in the European species.

Genus PSEUDANANCHYS Pomel

Pseudananchys Pomel, 1883, Classification méthodique et genera des échinides, p. 45.

Pseudananchys Pomel. Cotteau and Gauthier, in De Morgan, 1895, Mission scientifique en Perse, tome 3, pt. 2, p. 5.

Pseudananchys Pomel. Lambert, 1903, Mus. royal d'histoire nat. de Belgique Mém., tome 2, art. 4, p. 33.

Craginaster Lambert, 1903, Rev. crit. paléozoologie, tome 7, no. 4, p. 219. Type species *Holaster completus* Cragin, by monotypy.

Pseudananchys Pomel. Lambert and Thiéry, 1924, Nomenclature raisonnée des échinides, fasc. 6, p. 417. Typographical error.

Pseudananchys Pomel. Adkins, 1928, Texas Univ. Bull. 2838, p. 285.

Pseudananchys Pomel. Smiser, 1931, Jour. Paleontology, vol. 7, no. 2, p. 153.

Pseudananchys Pomel. Cooke, 1946, Jour. Paleontology, vol. 20, no. 3, p. 233.

Pseudananchys Pomel. Mortensen, 1950, Monograph of the Echinoidea, vol. 5, pt. 1, p. 71.

Type species *Ananchytes algira* Coquand (1862, p. 240, pl. 26, figs. 1, 2), by monotypy. Coquand's figures, as copied by Mortensen (1950, p. 72), show a tall, domed, flat-bottomed test with ovate horizontal outline. The straight, wide-open petals extend to or beyond the margin, the poriferous zones are all alike; the inner pores are circular or oval, and the outer pores are conspicuously elongated. The location of the periproct is not shown in these figures, but in *Holaster sylvaticus* Gauthier (Cotteau, Peron, and Gauthier, 1876, p. 66, pl. 5, fig. 2), which Cotteau, Peron, and Gauthier (1878, p. 84) regard as a synonym of *Pseudananchys algira*, it is below the ambitus but above the flat part of the lower surface. The periproct occupies this same location in *Pseudananchys completa* (Cragin) from the Grayson marl (Cenomanian) of Texas and in *P. stephensoni* Cooke, n. sp.

Pseudananchys differs from *Echinocorys* in the elongation of its ambulacral pores. Its buccal rosette appears to be less conspicuous, and its peristome is more strongly labiate. There may also be a consistent difference in the location of the periproct. In *Echinocorys* the periproct lies in a flattened area at the posterior end of the base. In *Pseudananchys completa* and apparently also in *P. stephensoni*, it lies well above the margin of the base though below the ambitus and hence not visible from above.

Pseudananchys stephensoni Cooke, n. sp.

Plate 9, figures 6-9

Test hemispherical, strongly arched above, flat below, faintly sulcate in front. Apical system central or behind the center, elongate, with four perforated genital plates, the anterior pair of pores widely separated from the posterior pair. Ambulacra narrow, subpetaloid; all petals nearly alike, extending nearly to the margin; pores elongated, the outer pores longer than the inner; anterior poriferous zones of paired petals straight; posterior zones gently curved, concave forward. Peristome far forward, transversely oval, labiate behind. Periproct terminal, not visible from above. Tubercles small, widely scattered on the upper surface, larger and closer together underneath; there is also a much finer tuberculation or granulation. Spines acicular.

Length of holotype, a crushed individual, 48.5 mm; width 49 mm; height 27 mm.

Occurrence.—Texas: From a creek on Waco and Gholson road between Aquilla and Whiterock Creeks, McClennon County;

supposed to have come from the *Exogyra ponderosa* marl (U.S.G.S. 3197, John K. Prather).

Geologic horizon.—Probably Austin chalk.

Types.—U.S.N.M. 108387.

Comparisons.—This species, known only from the type and two paratypes, all badly crushed, differs from *Pseudananchys completa* (Cragin) (Cooke, 1946, p. 233, pl. 34, figs. 7, 8) in the presence of an anterior depression. Its posterior genital pores are much closer together. In *P. stephensoni* the madreporic pores seem to be confined to the right anterior genital plate, whereas there are several separate areas of pores in the apical system of *P. completa*.

Genus *Holaster* Agassiz

Holaster Agassiz, 1836, Soc. sci. nat. Neuchâtel Mem., tome 1, p. 183.

Holaster Agassiz. Cooke, 1946, Jour. Paleontology, vol. 20, no. 3, p. 233.

Holaster Agassiz. Mortensen, 1950, Monograph of the Echinoidea, vol. 5, pt. 1, p. 47. Includes full synonymy.

Type species *Spatangus nodulosus* Goldfuss 1829, (1862, pt. 1, p. 139, pl. 45, figs. 6a-c) from the Cenomanian of Europe, designated by Savin (1905, *vide* Mortensen). This species has been identified by Wright (1864-1882, p. 310, pl. 72, figs. 1a-f) as *Holaster laevis* (Brongniart) (1822, pp. 97, 399). Cooke (1946, p. 234), following Lambert (1927, p. 269), identified the American Comanche species *Holaster simplex* Shumard as *Holaster laevis*, but *H. simplex* is proportionally longer, and its name is probably valid.

Holaster laevis has a cordate outline, with a weak anterior sulcus and a small posterior truncation. Its upper surface is strongly arched, its lower surface nearly flat. Its apical plates are arranged in two longitudinal rows headed by the anterior ocular. Its ambulacra are subpetaloid and flush; the anterior pair are curved slightly forward, the posterior pair are straight. The pores are oval, and the anterior poriferous zone of each paired ambulacrum is narrower than the posterior zone. The pores of the anterior ambulacrum are very small, circular, and arranged in diagonal pairs. There are no fascioles. The peristome is transversely oval and is set far forward. The periproct, which is at the top of a posterior truncation, is not visible from above.

The absence of a marginal fasciole distinguishes *Holaster* from *Cardiaster*.

Holaster feralis Cooke, n. sp.

Plate 9, figures 1-5; plate 10, figure 7

Test large, thin; horizontal outline ovate, widest in front; upper surface strongly inflated, highest in front with a very weak anterior flattening. Apical system central, not preserved. Ambulacra flush, anterior ambulacrum not petaloid, composed of plates ranging in length from about twice the width near the apex to nearly four times the width near the ambitus, pores

round or oval, pairs diagonal; paired ambulacra subpetaloid, composed of much longer, narrower plates, about eight times as long as wide, of uniform proportions, pore pairs occupying the center, pores slightly elongated and slightly inclined; anterior poriferous zones slightly the narrower. Interambulacral plates about twice as long as wide. Peristome anterior. Periproct marginal, rather small, nearly circular, flush. Tubercles perforated, widely scattered in all areas. Surface covered with faint granulation.

Length 78 mm; width 75 mm; height about 44 mm.

Occurrence.—Colorado: Wild Horse Park, 14 miles northwest of Pueblo (type, Colorado School of Mines, J. Harlan Johnson). Deadman Canyon, 14 miles south of Colorado Springs (U.S.G.S. 15402, J. S. Williams). Model Dome, Las Animas County, NE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 13, T 30 S, R 60 W (paratype, U.S.G.S. 22899, J. B. Reeside, Jr., and W. A. Cobban).

Geologic horizon.—Near bottom of type Greenhorn limestone, of basal Turonian age.

Type.—U.S.N.M. 108385, deposited by Colorado School of Mines; paratype U.S.N.M. 108386.

Remarks.—This species is proportionally wider and lower than *Holaster laevis* (Brongniart), its anterior depression is shallower, its posterior slope is more gradual, and its periproct is not above the margin. The generic assignment is tentative; though the ambulacra are like *Holaster*, the marginal location of the periproct is not typical.

Genus *CARDIASTER* Forbes

Cardiaster (part) Forbes, 1850, *Annals and Magazine Nat. History*, ser. 2, vol. 6, p. 442.

Cardiaster Forbes. Forbes, 1852, *United Kingdom Geol. Survey Mem.*, British Organic Remains, decade 4, plate 9, p. 1.

Cardiaster Forbes. D'Orbigny, 1854, *Paléontologie française*, Terrain crétacé, ser. 1, tome 6, p. 123.

Cardiaster Forbes. Desor, 1858, *Synopsis des échinides fossiles*, p. 344.

Cardiaster Forbes. Cotteau and Triger, 1869, *Échinides du département de la Sarthe*, p. 431.

Cardiaster Forbes. De Loriol, 1873, *Échinologie helvétique*, pt. 2, Période crétacé, p. 335.

Cardiaster Forbes. Stoliczka, 1873, *Palaeontologia Indica*, ser. 8, vol. 4, pt. 3, p. 21.

Cardiaster Forbes. Wright, 1878, *Monograph on the British fossil Echinodermata from the Cretaceous formations*, p. 293.

Cardiaster Forbes. Pomel, 1883, *Classification méthodique et genera des échinides*, p. 46.

Cardiaster Forbes. Duncan, 1889, *Linnean Soc. London Jour., Zoology*, vol. 23, p. 209.

Cardiaster Forbes. Savin, 1903, *Soc. histoire nat. de Savoie Bull.*, ser. 2, tome 8, p. 96.

Cardiaster Forbes. Jackson, 1922, *Carnegie Inst. Washington Pub.* 306, p. 69.

Cardiaster Forbes. Lambert and Thiéry, 1924, *Nomenclature raisonnée des échinides*, fasc. 6, p. 405.

Cardiaster Forbes. Smiser, 1935, *Mus. royal d'histoire nat. Mém.* no. 68, p. 67.

Cardiaster Forbes. Clark, 1946, *Carnegie Inst. Washington Pub.* 566, p. 360.

Cardiaster Forbes. Mortensen, 1950, *Monograph of the Echinoidea*, vol. 5, pt. 1, p. 51.

Type species *Spatangus cordiformis* Woodward 1833=*Spatangus granulosus* Goldfuss 1826, from the Upper Chalk of England and the Senonian of Europe, designated by Savin, 1903. D'Orbigny (1854–1860, p. 131, pl. 826) identified this species as *Spatangus ananchytis* Leske (1778, p. 243, pl. 53, figs. 1, 2), but Leske's figure looks unrecognizable. The species has been figured by Goldfuss (1826, pl. 45, fig. 3), Woodward (1833, pl. 5, fig. 6), Forbes (1852, pl. 9), Desor (1855–1858, pl. 39, figs. 7–9), Wright (1864–1882, pl. 69, figs. 2, 3), and Mortensen (1950, p. 52, fig. 43).

The most obvious difference between *Cardiaster* and *Holaster* is the presence of a marginal fasciole in *Cardiaster*, which passes under the periproct but is wanting or incomplete at the anterior end. The anterior depression is commonly deeper in *Cardiaster*, and the anterior end is wider, causing the horizontal outline to be strongly cordate rather than nearly oval, as in the type species of *Holaster*.

Cardiaster deciper Cooke, n. sp.

Plate 10, figures 3–6

Horizontal outline cordate, wider in front, tapering behind; upper surface moderately inflated; anterior sulcus subangular, extending from the apical system to the peristome, deeply indenting the margin; lower surface nearly flat; posterior end steeply truncated, slightly overhanging margin acutely rounded. Apical system very long and narrow, with four genital pores, the anterior and posterior pairs far apart. Paired ambulacra petaliferous; petals flush, radiating from two centers, anterior pair curving forward, posterior pair nearly straight; anterior poriferous zones of both pairs much narrower than the posterior; pores elongated, posterior pores of each zone longer than the anterior; pores near the tip of each zone slightly oblique. Peristome transversely oval, with a strong posterior lip. Periproct nearly circular; at the top of the posterior truncation, not visible from above. Two rows of large, nearly flush tubercles lie on each side of the anterior sulcus, one tubercle on each plate; two rows extend along the middle of the posterior interambulacral area; three tubercles adjoin the apical system in each of the posterior paired interambulacral areas; remainder of the upper surface covered with scattered small tubercles and fine granulation. A marginal fasciole extends along the sides and under the periproct.

Length 39 mm; width 36 mm; height 18.2 mm.

Occurrence.—Arkansas: Big Deciper Creek 5.4 miles southwest of Arkadelphia, Clark County (type, U.S.G.S. 13539, L. W. Stephenson). West of road to Nacatoch Bluff, 2.8 miles southwest of Okolona, Clark County (U.S.G.S. 13550, L. W. Stephenson).

Geologic horizon.—Saratoga chalk, of early Maestrichtian age.
Type.—U.S.N.M. 108389.

Comparisons.—This species, known only from the type and one fragment, appears to be closely related to *Cardiaster granulatus* (Goldfuss), but its petals are longer, and its ambulacral pores show only a slight tendency to deviate from a straight line, whereas those of *C. granulatus* are represented as conspicuously circumflex.

The specific name is a barbarous word; it should not be declined.

***Cardiaster leonensis* Stephenson**

Plate 11, figures 1-7

Cardiaster leonensis Stephenson, 1941, Texas Univ. Bull. 4101, p. 62, pl. 5, figs. 4-7; pl. 6, figs. 5, 6.

Test small for the genus, cordate, with a shallow, rounded frontal notch; upper surface rounded, slightly higher in front than behind; oral surface concave; truncated behind. Apical system in front of the center, elongated, with four genital plates; paired plates arranged in two parallel lines headed by the odd ocular plate. Paired petals extending more than halfway to the margin; anterior poriferous zones straight, narrow, pores small and circular; posterior poriferous zones slightly curved forward, much wider, inner pores oval, outer pores elongated. Peristome large, transversely oval, at the anterior third. Periproct nearly circular, slightly higher than wide, terminal, well up on a concave posterior truncation. Granulation fine; tubercles scattered. Marginal fasciole present.

Length of type 16 mm; width 16 mm; height 9 mm. Length of figured specimen from Cline Mountain 24 mm; width 23 mm; height 13.2 mm.

Occurrence.—Texas: Castroville road 1.2 miles west of Leon Creek, Bexar County (type, U.S.G.S. 15522, L. W. Stephenson). Cline Mountain, 2 miles south of Cline station, Uvalde County, beds immediately succeeding the Austin chalk (figured, U.S.G.S. Hill's no. 357, R. T. Hill). East end of Cline Mountain, Brackett quadrangle (U.S.G.S. 1774, T. W. Vaughan). Summit of hill north of Anacacho Mountain, 3 or 4 miles north of Cline (U.S.G.S. 1613b, R. T. Hill and T. W. Stanton). Quarry of Elm Creek, Kinney County (U.S.G.S. 16760, J. A. Udden). Agua de Fuera Creek, 1.7 to 2 miles northeast of Spofford, Kinney County (U.S.G.S. 18412, R. R. Bennett and A. N. Sayre). King's water hole 3 miles north of Hondo, Medina County (U.S.G.S. 12902, L. W. Stephenson).

Remarks.—*Cardiaster leonensis* is proportionately shorter than *C. deciper*, its posterior truncation is larger, its anterior sulcus is rounder and shallower, and the type is less than half as long.

Geologic horizon.—Corsicana marl, of late Maestrichtian age (type); Anacacho limestone and lower part of Taylor marl, of Campanian age.

Type.—U.S.N.M. 76279. Figured specimen U.S.N.M. 108390.

***Cardiaster curtus* Clark**

Plate 11, figure 14

Cardiaster curtus Clark, 1915, U. S. Geol. Survey Mon. 54, p. 84, pl. 37, figs. 1a-h.

Test small, cordate, the anterior furrow extending from the apex to the peristome; widest about the midpoint. Apical system central, large, elongated, with four large genital pores. Anterior paired petals curved slightly forward; posterior petals straight; anterior poriferous zones of all paired petals narrower than the others. Surface covered with fine granules and scattered tubercles. Marginal fasciole present.

Length 20.5 mm; width 19.3 mm; height about 12 mm.

Occurrence.—Montana: 25 miles southwest of Mingusville (now Wibaux).

Geologic horizon.—Upper part of Pierre shale, of latest Campanian age (*vide* W. A. Cobban).

Type.—U.S.N.M. 31201.

***Cardiaster smocki* Clark**

Plate 11, figure 8-10

Cardiaster smocki Clark, 1907, New Jersey Geol. Survey, Paleontology series, vol. 4, p. 298, pl. 13, figs. 9-11.

Cardiaster smocki Clark. Clark, 1915, U. S. Geol. Survey Mon. 54, p. 84, pl. 36, figs. 3a-c.

This species, described from an imperfect cast of the interior, is unrecognizable without better preserved topotypes. Its shape resembles that of *Cardiaster hilli* Cooke, from the Anacacho limestone of Texas, which may eventually prove to be the same species.

Occurrence.—New Jersey: Two and one-half miles northwest of Matawan.

Geologic horizon.—Merchantville clay, of Santonian age.

Type.—New Jersey State Museum, Trenton.

***Cardiaster marylandicus* Clark**

Plate 14, figures 1-5

Cardiaster marylandica Clark, 1916, Maryland Geol. Survey, Upper Cretaceous, p. 750, pl. 47, figs. 6-10.

Clark describes this species as follows: Test small, cordate, with pronounced anterior grooves; upper surface slightly convex, lower surface flat. Ambulacra wide. Apical system moderately elongated. Peristome very near anterior margin. Periproct oval and situated rather high on truncated posterior margin.

Length 18 mm; width 18 mm; height 11.5 mm.

Occurrence.—Maryland: Brightseat, Prince George County.

Geologic horizon.—Monmouth formation, of late Maestrichtian age.

Type.—Maryland Geological Survey.

Comparison.—Clark compares this species with *Cardiaster smocki*, but finds it to be more sharply contracted posteriorly and to have "a more pronounced anterior surface."

Genus ISOMICRASTER Lambert

Micraster (Isomicraster) Lambert, 1901, Carte géol. det. France, Mém., Recherches sur la craie supérieure, pt. 1, fasc. 2, chap. 4, p. 969.

Micraster (*Isomicraster*) Lambert. Lambert, 1903, Soc. géol. France Bull., ser. 4, tome 3, p. 78.

Micraster (*Isomicraster*) Lambert. Lambert and Thiéry, 1924, Nomenclature raisonnée des échinides, fasc. 6, p. 483.

Isomicraster Lambert. Mortensen, 1950, Monograph of the Echinoidea, vol. 5, pt. 1, p. 352; 1951, pt. 2, p. 565.

Type species *Isomicraster stolleyi* Lambert, originally identified as *Epiaster gibbus* (Lamarck) by Schlüter, from the Cretaceous of Lüneburg, Prussia. Schlüter's figures are copied by Mortensen (1950, p. 353, figs. 249). They show a subconical test with rather short, straight, moderately sunken petals, all alike. The anterior ambulacrum is sunken all the way to the peristome, which is far forward and strongly labiate. The periproct lies on the posterior truncation, above the base. The species is said to have four genital pores.

Isomicraster was described as a subgenus or section under *Micraster*. Its apical system (in the American species) is like that of *Micraster coranguinum*, but its anterior petal is quite different, being just like the paired petals, with elongated, conjugate pores, whereas *Micraster* has small pores separated by a bead. *Isomicraster* also lacks complete fascioles, though one American species shows traces of an incomplete peripetalous fasciole. *Epiaster*, also, lacks fascioles, but the pores of the anterior petal of its type species, *Epiaster crassissimus* (Defrance),¹ are different.

The subconical shape seems to be characteristic of *Isomicraster*; likewise the decoration with scattered small, sunken tubercles and fine, close granules.

Isomicraster rossi Cooke, n. sp.

Plate 11, figures 15, 16

Test subconical or dome-shaped with a slight emargination in front. Apical system apparently nearly central, with four genital pores, ethmophractic, the posterior ocular plates in contact. Ambulacra petaloid; petals all alike, slightly sunken, rather long, reaching nearly to the margin; inner pores circular or oval, outer pores elongate, pores conjugate; interporiferous zones about equal to the poriferous. Peristome at the anterior quarter, strongly lipped. Periproct not preserved, apparently supramarginal, on a posterior truncation. Surface coarsely granular; tubercles scattered, small, sunken. Faint traces of a partial fasciole in anterior interambulacra.

Length of larger cotype 51 mm; width about 49 mm; height (distorted) 29 mm.

Occurrence.—Texas: Terlingua region near Rio Grande a short distance east of Walker Prospect and south of the highway, loose on surface (U.S.G.S. 16855, C. P. Ross).

Geologic horizon.—Eagle Ford shale, of Turonian age.

Types.—U.S.N.M. 103892.

¹ Lambert's (1895, p. 156) designation of *E. crassissimus* as the type appears to be valid though Lambert and Thiéry (1909-1925, p. 477) later designate *E. trigonalis* (Desor).

Comparisons.—*Isomicraster rossi* is represented by seven individuals, all of which are crushed and fragmentary. It appears to have longer petals than *Isomicraster mexicanus* Lambert (1936, p. 371, fig. 2), from the lower Senonian of Chiapas. Its granulation is somewhat coarser than that of *Isomicraster danei* Cooke from the Annona chalk of Arkansas, which lacks the partial fasciole and has a deeper anterior emargination.

Isomicraster danei Cooke, n. sp.

Plate 11, figures 11-13

Test subconical or dome-shaped, steeply sloping forward into a sulcus, rostrate behind. Apical system central. Petals long, depressed, not expanding, extending almost to the margin; anterior pair straight, widely spreading; posterior pair slightly curved backward; anterior petal like the others; poriferous zones equalling the interporiferous zone in width; pores conjugate, outer pores slightly longer than the inner pores. Peristome not preserved. Periproct circular, at the top of a slightly overhanging V-shaped truncation, not visible from above. Tubercles small, evenly spaced. Surface finely granulated. No fascioles.

Length 57 mm; width as preserved 53 mm; height about 30 mm.

Occurrence.—Arkansas: Rocky Comfort, Little River County (U. S. G. S. 13506, Carle H. Dane).

Texas: Cut of St. Louis Southwestern Railroad 1/3 mile southeast of Bailey, Fannin County, internal mold (U. S. G. S. 10553, L. W. Stephenson).

Geologic horizon.—Top of Gober tongue of the Austin chalk, of Santonian age.

Type.—U.S.N.M. 108391.

Comparisons.—*Isomicraster danei* has deeper petals, a deeper anterior sulcus, and finer granulation than *I. rossi* Cooke, which occupies an older bed. It is known only from the type, which lacks most of the lower surface, and one internal mold, from Texas, which is not surely identified.

Genus *BARNUMIA* Cooke, n. gen.

Test weakly cordate, strongly inflated. Apical system ethmophractic, the posterior ocular plates in contact; four genital pores. Five petals, all alike, the anterior pair the longest, open distally, flush; pores conjugate, outer pores elongated, inner pores oval. Peristome nearly round, not lipped. Periproct probably on lower surface, longitudinally elongated. Tubercles perforated, crenulate, areoles conspicuous. Marginal fasciole continuous.

Type species *Barnumia browni* Cooke.

The taxonomic position of *Barnumia* is uncertain. Its ethmophractic apical system allies it with the Hemiassteridae, but its anterior petal is like the others, and its petals are flush, not sunken as in most members of that family. Its fasciole, which may not be quite marginal, suggests that of *Holopneustes* Cotteau. Its inflated shape, without definite margin, is unusual among the spatangoids. Its petals are much like those

of *Pseudananchys* Pomel, but their poriferous zones do not diverge.

Barnumia browni Cooke, n. sp.

Plate 16, figures 2-5

Test moderately large, weakly cordate; upper surface strongly inflated, somewhat pointed at the apex; lower surface apparently strongly convex; margin broadly rounded. Apical system central(?), ethmophractic, the two posterior ocular plates and the two posterior genital plates touching each other; all four genital plates perforated. Anterior petal like the others, anterior paired petals the longest; poriferous zones straight, not diverging, open at the outer ends; pores conjugate, the inner pores oval, the outer pores elongated, pores set at a slight angle to each other, but the conjugations are transverse. Petals surrounded at a distance by a fasciole, which is not indented. Peristome nearly circular, apparently without lips. Periproct longitudinally elongated, probably inframarginal. Tubercles crenate, perforated, on large areoles, larger on the lower surface.

Diameter about 40 to 50 mm.

Occurrence.—Guatemala: East end of the airstrip near Rio de la Pasion at Santa Amelia, Peten (U.S.N.M. accession 195206, Barnum Brown).

Geologic horizon.—Campanian?

Types.—Three cotypes, U.S.N.M. 108407.

Remarks.—All three cotypes are so badly crushed that it is difficult to visualize the original shape. They appear to have been almost spherical, though the apex probably was slightly pointed and there was a shallow anterior depression. The peristome probably was not very far forward, and the periproct below the indefinite periphery.

The species and genus are named in honor of the collector, Dr. Barnum Brown.

Genus *HEMIASTER* Desor

Hemiaster Desor in Agassiz and Desor, 1847, *Annales sci. nat. (zoologie)*, tome 8, p. 16; Catalogue raisonné des échinodermes (reprint), p. 122.

Hemiaster Desor. D'Orbigny, 1855, *Paléontologie française*, Terrain crétacé, ser. 1, tome 6, p. 220.

Hemiaster Desor. Cooke, 1946, *Jour. Paleontology*, vol. 20, no. 3, p. 222.

Hemiaster Desor. Mortensen, 1950, *Monograph of the Echinoidea*, vol. 5, pt. 1, p. 378. Gives full synonymy.

Type species *Spatangus bufo* Brongniart, from the Cenomanian of France, designated by Savin (1903, p. 76). This species has been figured by Agassiz and Desor (1847, pl. 16, fig. 7), by D'Orbigny (1854-1860, pl. 873), and by Mortensen (1950, p. 380, fig. 272), who copies three of D'Orbigny's figures. Specimens in the United States National Museum from Les Vaches Noires, near Dives, Dept. du Calvados, France, which appear to be correctly identified, are nearly equidimensional, much higher behind than in front, with

a very shallow anterior depression. The apical system is slightly behind the center, definitely ethmophractic, with the posterior ocular plates in contact. It has four genital pores, the lateral pair is as far apart as the anterior pair. The paired petals are straight, short, extending little more than halfway to the margin, which is broadly rounded; they are not deeply depressed; the anterior pair is nearly twice as long as the posterior pair. The poriferous zones of the paired petals are about equal in width to the interporiferous zones; the pores are slightly elongated and are parallel. The plates of the anterior ambulacrum are about twice as broad as those of the petals, and the zygopores are consequently farther apart; the pores of each pair are very slightly elongated, and they are set at an angle to each other, as in a chevron; the pores are separated by a small bead. The peristome lies at the anterior third; it is semilunate, rather large, bordered by a thin rim, and weakly labiate behind. The periproct is circular or oval, higher than wide; it stands near the top of a posterior nearly vertical truncation and is barely visible from above. The peripetalous fasciole, the only one detected, is very slightly indented between the lateral petals.

Key to the American species of *Hemiaster*²

- Posterior petals short, anterior depression shallow, apex posterior
- Posterior petals widely spreading----- *H. humphreysanus*
- Posterior petals not widely spreading
- Lateral genital pores close together, tuberculation coarse----- *H. wetherbyi*
- Lateral genital pores far apart, tuberculation finer----- *H. arcolensis*
- Posterior petals long, anterior depression deeper, apex central or anterior
- Apex central, posterior slope steep
- Posterior ocular plates in contact, fasciole deeply incurved----- *H. jacksoni*
- Posterior ocular plates not in contact, fasciole not deeply incurved----- *H. texanus*
- Apex anterior, posterior slope not steep- *H. sabinal*

Hemiaster humphreysanus Meek and Hayden

Plate 12, figures 1-4

Hemiaster? *humphreysanus* Meek and Hayden, 1856, *Acad. Nat. Sci. Philadelphia Proc.*, vol. 9, p. 147.

Hemiaster humphreysanus Meek and Hayden. Meek, 1876, *U. S. Geol. and Geog. Survey Terr. Final Rept.*, vol. 9, p. 5, pl. 10, figs. 1a-g.

Hemiaster humphreysanus Meek and Hayden. Clark, 1891, *Johns Hopkins Univ. Circ.*, vol. 10, no. 87, p. 77.

Hemiaster humphreysanus Meek and Hayden. Clark, 1893, *Johns Hopkins Univ. Circ.*, vol. 12, no. 103, p. 52.

Hemiaster humphreysanus Meek and Hayden. Clark, 1893, *U. S. Geol. Survey Bull.* 97, p. 88, pl. 48, figs. 1a-f.

² Species not keyed: *Hemiaster ungula* Morton, *H. welleri* Clark, *H. kummeli* Clark, *H. beecheri* Clark, *H. delawarensis* Clark, *H. amelianus* Cooke.

- Hemiaster humphreysanus* Meek and Hayden. Clark, 1915, U. S. Geol. Survey Mon. 54, p. 95, pl. 49, figs. 2a-f.
- Hemiaster humphreysanus* Meek and Hayden. Dowling, 1917, Canada Dept. Mines Mem. 93, p. 47, pl. 35, figs. 1-1c. After Meek, 1876.
- ?*Hemiaster humphreysanus* Meek and Hayden. Ravn, 1918, Meddelelser om Grønland, vol. 56, p. 334, pl. 7, figs. 1, 2.
- Toxaster (Plotoxaster) humphreysi* (Meek and Hayden). Lambert and Thiéry, 1924, Nomenclature raisonnée des échinides, fasc. 6, p. 437.

Horizontal outline ovate, greatest width in front of the center, slightly indented in front; upper surface inflated, somewhat higher behind than in front; lower surface gently convex. Apical system at the posterior quarter; posterior ocular plates in contact; lateral genital plates in contact, madreporite central, swollen; four genital pores. Petals moderately sunken, slightly sinuous; anterior pair much longer than posterior pair, diverging at an angle approximating 85°; posterior petals short, diverging at an angle approximating 115°; poriferous zones about as wide as interporiferous zones; pores oval to moderately elongated, pores of each pair separated by a raised thread. Anterior ambulacrum subpetaloid; pores circular, pores of each pair separated by a small bead. Petals surrounded by a slightly indented, wide fasciole. Peristome far forward; sunken; strongly labiate behind. Periproct near the top of an inconspicuous, nearly vertical depression; slightly higher than wide. Tubercles on scaly scrobiculi; largest on plastron; tubercles within the fasciole small and crowded. Basal part of posterior ambulacra bare.

Length of type 31 mm; width 30.6 mm; height 20.2 mm.

Occurrence.—Wyoming: Upper Yellowstone 150 miles from mouth (type). Sec. 18, T. 12 N., R. 57 E., Terry Field (U.S.G.S. 6641; F. Herald).

Utah: Westwater Canyon just below the junction of Middle and West (main) Westwater Creek a short distance above Robinson Ranch (U.S.G.S. 13268, E. Spieker and J. B. Reeside, Jr.).

Arkansas: Ouachita River 1.5 miles above Arkadelphia (U.S.G.S. 13541, L. W. Stephenson and C. H. Dane). Nacatoch Bluff, Little Missouri River (U.S.G.S. 7462, L. W. Stephenson).

Mississippi: Bullock's old mill 2 miles south of Dumas, Tippah County (casts).

Greenland: Patoot (*vide* Ravn).

Geologic horizon.—Upper part of Pierre shale, equivalent to Mobridge member in Wyoming; Sego sandstone member of Mesaverde formation in Utah; Nacatoch sand in Arkansas; Ripley formation in Mississippi; all of late Senonian (Maestrichtian) age.

Type.—U.S.N.M. 331; figured specimens U.S.N.M. 108393, 108394.

Remarks.—The type is badly decorticated, but details of the sculpture are shown by specimens from U.S.G.S. 6641 and U.S.G.S. 13541.

Hemiaster beecheri Clark

Hemiaster beecheri Clark, 1915, U. S. Geol. Survey Mon. 54, p. 96, pl. 50, figs. 2a-c.

Clark describes this species as follows:

Test large, cordiform, elevated; upper surface inflated, depressed posteriorly; ambulacra broadly depressed on dorsal surface, anterior ambulacrum in broad sulcus.

Length 70 mm (?); width 59 mm; height 41 mm.

Occurrence.—South Dakota: Sage Creek.

Geologic horizon.—Virgin Creek member of Pierre shale, of late Campanian age.

Type.—Peabody Museum, Yale University, 1863.

Remarks.—Clark says that this species is based on only one specimen. His figures show it as a broken cast of the interior to which some pieces of shell are attached.

Hemiaster wetherbyi De Loriol

Plate 12, figures 17, 18

Hemiaster wetherbyi De Loriol, 1887, Recueil zool. Suisse, tome 4, p. 391, pl. 17, figs. 5, 6.

Hemiaster lacunosus Slocum, 1909, Field Mus. Nat. History Pub. 134, Geol. Ser. vol. 4, no. 1, p. 10, pl. 2, figs. 1-7. Not *Hemiaster lacunosus* (Goldfuss) D'Orbigny 1847.

Hemiaster lacunosus Slocum. Clark, 1915, U. S. Geol. Survey Mon. 54, p. 97, pl. 50, figs. 3a-d; pl. 51, figs. 1a-i.

Hemiaster bezari Clark, 1915, U. S. Geol. Survey Mon. 54, p. 89, pl. 46, figs. 1a-e.

Hemiaster (Leymeriaster) bezari Clark. Lambert and Thiéry, 1924, Nomenclature raisonnée des échinides, fasc. 6, p. 500.

Hemiaster (Intergraster) slocumi Lambert in Lambert and Thiéry, 1924, Nomenclature raisonnée des échinides, fasc. 6, p. 504. For *H. lacunosus* Slocum.

Hemiaster (Leymeriaster) bezari Clark. Adkins, 1928, Texas Univ. Bull. 2838, p. 298.

Hemiaster wetherbyi De Loriol. Lambert, 1935, Soc. géol. France Bull., ser. 5, t. 5, p. 372.

Hemiaster bezari Clark. Stephenson, 1941, Texas Univ. Bull. 4101, p. 65, pl. 6, figs. 7, 8; pl. 7, figs. 5-7.

Hemiaster behrensensis Stephenson, 1941, Texas Univ. Bull. 4101, p. 67, pl. 7, figs. 8-10.

Test small, plump, subovate; upper surface somewhat higher behind; lower surface inflated; margin rounded, truncated behind. Apical system behind the center; genital pores inconspicuous; madreporite large and tumid. Paired petals wide, straight, closed, moderately sunken; anterior pair twice as long as posterior pair; poriferous zones wider than interporiferous; pores elongate-oval to drop-shaped; pores of each zygopore connected by a raised thread. Anterior petal straight, open, moderately sunken, the depression barely indenting the margin; pores small, zygopores short, pores separated by a conspicuous bead. Peripetalous fasciole broad, conspicuous, barely indented between the petals. Peristome anterior, one-third the total length from the margin, strongly labiate behind. Periproct small, slightly elongated longitudinally; well up on the vertical

posterior truncation. Tubercles large, close together, scrobiculate; larger and more deeply scrobiculate on lower surface. Sternum bordered by broad, straight rugose bands.

Length of figured specimen 24 mm; width 23 mm; height 18 mm.

Occurrence.—Alabama: *Prairie Bluff chalk.*—Prairie Bluff, Wilcox County (U.S.G.S. 6793, 11650, L. W. Stephenson). Moscow Bluff, Tombigbee River (U.S.G.S. 5643, S. W. McCallie; U.S.G.S. 6438, L. W. Stephenson). Old Canton Landing, Alabama River, 14 miles below Pine Barren Creek (U.S.G.S. 6439, L. W. Stephenson). The Larry Johnson Bluff on Alabama River just above the mouth of Tearup Creek (U.S.G.S. 310, L. C. Johnson). North side of 300-foot knob in NE $\frac{1}{4}$ sec. 33, T 20 N, R 2 W, Sumter County (U.S.G.S. 18145, W. H. Monroe). *Ripley formation.*—Demopolis road 3.9 miles northeast of Coatopa (U.S.G.S. 11663, L. W. Stephenson).

Mississippi: *Prairie Bluff chalk.*—About 3 miles south of New Albany, Union County, at foot of north-facing slope of Kings Creek valley (U.S.G.S. 6872, L. W. Stephenson). Wallerville, Union County (U.S.G.S. 9604, L. W. Stephenson and Bruce Wade). Pontotoc (U.S.G.S. 6470, 6852, 6853, 17206, L. W. Stephenson). $1\frac{1}{4}$ miles south of Pontotoc (U.S.G.S. 11652, L. W. Stephenson and C. W. Cooke). 2 miles south of Pontotoc (U.S.G.S. 6856, L. W. Stephenson). Houlika Creek 1 mile east of Houston, Chickasaw County (U.S.G.S. 612, T. W. Stanton). North-facing slope of Chookatonkchie Creek 3 miles east-northeast of Houlika Station, SE $\frac{1}{4}$ sec. 10, T 12 S, R 3 E, Chickasaw County (U.S.G.S. 17227, W. H. Monroe). East-facing bank of Sockahoma Creek, SE corner sec. 4, T. 13 S, R 3 E, Chickasaw County (U.S.G.S. 17258, W. H. Monroe). Road cut, NE $\frac{1}{4}$ sec. 14, T 13 S, R 3 E, Chickasaw County (U.S.G.S. 19085, W. H. Monroe). SE corner sec. 3, T 13 S, R 3 E, 5.5 miles southeast by south of Houlika (U.S.G.S. 17215, W. H. Monroe). Gullies on campus of A. & M. College near Starkville, Oktibbeha County (U.S.G.S. 6843, W. N. Logan). *Ripley formation.*—Old Tupelo road 5 miles east of Pontotoc (U.S.G.S. 6857, L. W. Stephenson). Pontotoc County 4 miles southwest of Troy (U.S.G.S. 17261, L. W. Stephenson). SW $\frac{1}{4}$ sec. 15, T 11 S, R 4 E, 0.4 mile east of Troy (U.S.G.S. 17259, W. H. Monroe). Shannon Road $\frac{1}{4}$ mile east of Troy (U.S.G.S. 6471, L. W. Stephenson). Stream bed near Mobile & Ohio Railroad about 5 miles northeast of Houston, Chickasaw County (U.S.G.S. 6851, L. W. Stephenson).

Arkansas: *Saratoga chalk.*—Clark County 1.6 miles southwest of Okolona (U.S.G.S. 13403, L. W. Stephenson and Carle H. Dane). 2.3 miles southwest of Okolona (U.S.G.S. 13405, 13407, L. W. Stephenson and Carle H. Dane). 2.8 miles southwest of Okolona, west of road to Nacatoch Bluff (U.S.G.S. 13550, L. W. Stephenson). Arkadelphia road 3.3 miles east of Okolona (U.S.G.S. 13549, L. W. Stephenson). Big Deciper Creek 5.4 miles southwest of Arkadelphia (U.S.G.S. 13539, L. W. Stephenson). 7.4 miles southwest of Arkadelphia (U.S.G.S. 13537, L. W. Stephenson and Carle H. Dane). Okolona Road about 7.5 miles southwest of Arkadelphia (U.S.G.S. 13406, L. W. Stephenson and Carle H. Dane). Ozan road 3.1 miles north of Washington, Hempstead County (U.S.G.S. 13408, L. W. Stephenson). Ozan road 3.2 miles north of Washington (U.S.G.S. 13410, L. W. Stephenson). Road cut at north edge of Saratoga, Howard County (U.S.G.S. 13404, L. W. Stephenson). *Marlbrook marl.*—Big Deciper Creek 5 miles southwest of Arkadelphia on the lower road to Okolona (U.S.G.S. 7460, L. W. Stephenson). *Nacatoch sand.*—Old Marlbrook plantation 6 or 7 miles northeast of

Washington (U.S.G.S. 7476, L. W. Stephenson). 2 miles north-east of Washington (U.S.G.S. 7469, L. W. Stephenson). 2.1 miles northeast of Washington (U.S.G.S. 7471, L. W. Stephenson).

Texas: *Corsicana marl.*—San Antonio road, Bexar County, 6 miles east of Castroville road (U.S.G.S. 15502, 16156, 16667, L. W. Stephenson). Earth tank just north of Castroville road 1 mile west of crossing of Leon Creek, Bexar County (U.S.G.S. 15522, L. W. Stephenson). Standard fuller's earth mine 1.25 mile south by east of Padrone Hill, 14 miles west of San Antonio, Bexar County (U.S.G.S. 15520, L. W. Stephenson). Road leading south from Castroville road just east of abandoned fuller's earth pits 0.8 mile south of Castroville road, about 14 miles west by south of San Antonio (U.S.G.S. 15623, L. W. Stephenson). Hill south of the Seguin-San Antonio highway 2.5 miles west of McQueeney, Guadalupe County (U.S.G.S. 15523, L. W. Stephenson). *Neylandville marl.*—2.5 miles air line south of Ben Hur, Limestone County (U.S.G.S. 15543, L. W. Stephenson).

Geologic horizon.—Navarro group and equivalents (Maestric-tian).

Type.—Unknown; from Wahalak, Kemper County, Mississippi, probably from Prairie Bluff chalk. Type of *H. lacunosus* Slocum, from Pontotoc, Miss., Chicago Natural History Museum 10342, probably from Prairie Bluff chalk. *H. bezari* Clark, from Bexar County, Texas, U.S.N.M. 8330. Type of *H. benhurensis* Stephenson, from U.S.G.S. 15543, 2.5 miles south of Ben Hur, Limestone County, from Neylandville marl, U.S.N.M. 76282.

Figured specimen.—U.S.N.M. 108398, from U.S.G.S. 6856.

Comparisons.—This species appears to have been mistaken for *Hemiasler stella* (Morton), an Eocene species from New Jersey, by Morton (1834, p. 78), D'Orbigny (1854–1860, p. 246), and Clark (1915, p. 93), but it is not closely related to that species, differing in shape, in the arrangement of its apical plates, and in other features. It is higher in front and lower behind than *Hemiasler bufo* as figured by D'Orbigny (1854–1860, pl. 873). It is easily distinguishable from *Hemiasler arcolensis* Cooke, which occurs in a lower zone, by its sunken tubercles.

Hemiasler arcolensis Cooke, n. sp.

Plate 12, figures 12–16

Horizontal outline suboval; strongly convex above, weakly convex below; slightly higher behind than in front. Apical system slightly behind the center; four genital pores far apart; madreporite small, central, tumid. Paired petals straight, wide, evenly concave; anterior pair longer than the posterior pair; pores plainly elongated; poriferous zones about as wide as the interporiferous zones. Anterior ambulacrum wide, evenly concave; zygopores very narrow, pores separated by an erect, flattened bead; very slightly depressed on the margin. Peristome at the anterior third, bordered by a continuous raised rim, strongly labiate behind. Periproct small, slightly taller than wide, set high up on the weakly truncated posterior end. Peripetalous fasciole wide, conspicuous, very slightly incurved between the petals. Tubercles small, perforated, set on small flakelike socles, which are not at all depressed. Sternum bordered by smooth ambulacral areas.

Length 28 mm; width 26.2 mm; height 20.8 mm.

Occurrence.—Alabama: 3 miles northeast of Haynesville, Lowndes County, in T 14 N, R 15 E. (D. H. Eargle)

Geologic horizon.—Arcola limestone member of the Mooreville chalk, of Santonian age.

Type.—U.S.N.M. 108397.

Comparisons.—This species, which is represented only by the figured type and two crushed individuals from the same locality, resembles to some extent *Hemiaster wetherbyi* de Loriol but it is wider behind, its apical system is more nearly central, the beads on its anterior zygopores are smaller and flattened, its lateral genital pores are farther apart, and its tubercles are smaller and not at all sunken. It is very similar to *Hemiaster minimus* (Agassiz) as figured by D'Orbigny (1854–1860, p. 225, pl. 872), no specimens of which are available for direct comparison. That species seems to be somewhat wider behind and somewhat taller.

Hemiaster jacksoni Maury

Plate 12, figures 5–11

Hemiaster cristata Stoliczka? White, 1887, Mus. Nac. Rio Janeiro Archivos, vol. 7, p. 261, pl. 27, figs. 4–6.

?*Hemiaster* sp. Böse, 1918, Texas Univ. Bull., no. 1856, p. 232, pl. 20, figs. 6–10.

Hemiaster jacksoni Maury, 1925, Serv. geol. e min. do Brazil, Mon. 4, p. 519.

Hemiaster jacksoni Maury. Maury, 1930, Serv. geol. e min. do Brazil, Mon. 8, p. 119, pl. 5, figs. 2, 7.

Hemiaster jacksoni Maury. Maury, 1936, Serv. geol. e min. do Brazil, Mon. 11, p. 279, pl. 3, figs. 1, 2, 8–10.

Leiotomaster bösei Smiser, 1936, Jour. Paleontology, vol. 10, no. 6, p. 476, pl. 64, figs. 4–8. (Error for *Leiotomaster*.)

Hemiaster calvini Clark. Jones, 1938, Geol. Soc. America Bull., vol. 49, no. 1, p. 135, pl. 13, figs. 17–20.

Horizontal outline suboval; upper surface inflated; lower surface flattish, slightly convex in the sternal region; margin rounded; posterior truncation steep. Apical system central; four genital plates, lateral perforations closer together than front or back pairs; madreporite extending between the posterior lateral genital plates but not separating the posterior ocular plates, which are in contact. Petals straight, sunken, rather long, the anterior pair the longer; pores elongated, not conjugate; poriferous zones somewhat wider than the interporiferous. Anterior petal sunken in a broad depression, which extends to the peristome, slightly indenting the margin; pores small, close together, pairs diagonal, the inclination increasing away from the apex. Peristome reniform or subpentagonal, with a weak posterior lip. Periproct high up on the posterior truncation, plainly visible from above. Peripetalous fasciole broad and rather ill defined; strongly indented on each side. Tubercles rather widely scattered; larger on the anterior end.

Length of figured specimen from Brazil 26.7 mm; width 25.0 mm; height 18 mm. Length of figured specimen from Texas 26.6 mm; width 26.1 mm; height 17 mm.

Occurrence.—Brazil: Sergipe province, probably from Bom Jesus, near Laranjeiras (U.S.G.S. 16952).

Mexico: Sierra de Santa Ana, Coahuila (Univ. Michigan 16669, 16670, T. S. Jones, figured by Jones).

Texas: Bluff on Sycamore Creek, Kinney County, 1 mile above Ross and 12.4 miles southeast of Del Rio (U.S.G.S. 10839, 10840, L. W. Stephenson). Hill north of highway crossing of Lozier Canyon, 21 miles west of Langtry (T. W. Stanton and W. P. Popenoe). Highway 90, Rose Ranch, Kinney County ½ mile east of Arenosa Creek, 8¼ miles east of Brackettville, lat. 29°15'55", long. 100°14'50" (U.S.G.S. 18414, R. R. Bennett). 1 mile southwest of Whitehead-Wordlaw ranch house, 3.5 miles southwest of Standart (U.S.G.S. 23091, R. R. Bennett).

Geologic horizon.—Eagle Ford shale in Texas, member 2 of Indidura formation in Mexico, early Turonian of Brazil.

Types.—Presumably at the Museu Nacional, Rio de Janeiro. Figured specimens U.S.N.M. 108395, 108396. Type of *Hemiaster bösei* at Princeton University (*vide* Smiser).

Remarks.—The preceding description is based on the figured specimen from Brazil (pl. 12, figs. 5–11), one of a mixed collection numbered U.S.G.S. 16952. The original label, in C. A. White's handwriting, reads "*Hemiaster cristatus* Stoliczka, Lastro Maroim, and Bom Jesus, Province of Sergipe." The matrix of the *Hemiasters* is yellowish earthy limestone like that described (White, 1887, p. 13) at Bom Jesus, near Laranjeiras, differing conspicuously from the white oolitic limestone at Lastro, just below the town of Maroim. White (1887, p. 268) records the species from Lastro, apparently an error caused by the mixed collection. Maury (1936, p. 279) repeats this locality and attributes the species there to the middle Albian. She (Maury, 1936, tables facing p. 34) correlates the limestone at Bom Jesus with the lower Turonian of Europe and the Eagle Ford shale of Texas, which is the horizon of all the specimens from the United States.

Hemiaster texanus Roemer

Plate 13, figures 1–4

Hemiaster texanus Roemer, 1849, Texas, p. 393.

Hemiaster texanus Roemer. Roemer, 1852, Kreidebildungen von Texas, p. 85, pl. 10, fig. 4a–c.

Hemiaster americanus Giebel, 1853, Naturwiss. Verein für Sachsen und Thüringen in Halle Jahresber., Band 5, p. 372.

Hemiaster texanus Roemer. Clark, 1893, U. S. Geol. Survey Bull. 97, p. 86, pl. 47, figs. 1a–i.

Hemiaster texanus Roemer. Hill and Vaughan, 1898, U. S. Geol. Survey Eighteenth Ann. Rept., pt. 2, pl. 61, figs. 1a, 1b. (After Clark, 1893, figs. 1a, 1b.)

Hemiaster texanus Roemer. Hill, 1902, U. S. Geol. Survey Twenty-first Ann. Rept., pt. 7, pl. 45, fig. 5. (After Clark, 1893, fig. 1a.)

Hemiaster texanus Roemer. Clark, 1915, U. S. Geol. Survey Mon. 54, p. 94, pl. 49, figs. 1a–j.

Hemiaster texanus Roemer. Adkins, 1928, Texas Univ. Bull. No. 2838, p. 299, pl. 34, figs. 4, 5.

Hemiaster americanus Giebel. Adkins, 1928, Texas Univ. Bull. No. 2838, p. 299.

Horizontal outline cordate-subquadrate, indented in front, truncated behind; upper surface rather high; lower surface slightly inflated. Apical system nearly central, ethmolytic, the madreporite separating the posterior oculars, with four perforated genital plates, the lateral perforations much closer together than the front or back. Paired petals long, straight, deeply indented, the anterior pair the longer; poriferous and

interporiferous zones equal in width; pores elongated, conjugated; open distally. Anterior ambulacrum subpetaloid; plates long and narrow; pores of each zygopore round, close together, separated by a small flattened bead; deep, rounded ambulacral furrow extending to the peristome. Peristome reniform, sunken, strongly labiate behind; surrounded by four paired ambulacral furrows with small beaded zygopores. Periproct well up on a sloping, slightly concave posterior truncation; visible from above. Peripetalous fasciole slightly indented between the lateral petals. Tubercles at anterior end surrounded by fine granulation; tubercles on plastron resting on scaly socles. Posterior paired ambulacra bare underneath.

Length of figured specimen from the Anacacho limestone 38.3 mm; width 36.5 mm, height 22.8 mm.

Occurrence.—Texas: Austin chalk.—Waterfall of Guadalupe below New Braunfels (type, *vide* Roemer). Hondo Creek 5½ miles west-northwest of Hondo (U.S.G.S. 14711, N. H. Darton). Tequiquite Creek 28.8 miles northwest of Eagle Pass, ¾ to 1 mile below the crossing of the Del Rio road, in Maverick County (U.S.G.S. 8229, 10856, L. W. Stephenson).

Anacacho limestone.—Sabinal River, Uvalde County, 2½ to 3½ miles above Sabinal (U.S.G.S. 1878, T. W. Vaughan; U.S.G.S. 7706, 7708, L. W. Stephenson; U.S.G.S. 14708, N. H. Darton). Sabinal-Utopia road 5.5 miles north of Sabinal (U.S.G.S. 7711). 2 miles north of Sabinal (U.S.G.S. 22407, Wm. T. Watkins). Cline Mountain, 2 miles east of Cline Station, beds immediately above the Austin chalk (U.S.G.S. 357, R. T. Hill). Potranca road, 2 miles west of Culebra road forks, West San Antonio quadrangle, Bexar County (U.S.G.S. 16462, A. N. Sayre). Hondo (or Kiner) Creek about 1.6 miles above Kings Water Hole, Medina County (U.S.G.S. 12908, L. W. Stephenson).

Taylor marl.—2¼ miles east by north of Rockwell (U.S.G.S. 9724, L. W. Stephenson).

Geologic horizon.—Austin chalk (type), Anacacho limestone, and Taylor marl, of Senonian age.

Figured specimen.—U.S.N.M., 108399, from U.S.G.S. 1878.

Remarks.—This species has been identified as *Hemiaster texanus* solely on the basis of Roemer's description and figures, which appear to be very accurate. None of the specimens from the Austin chalk are well enough preserved to make the identification certain, but those from the Anacacho limestone, which are plentiful and in good condition, agree well with Roemer's figures. The type locality is reported as the waterfall of the Guadalupe at New Braunfels, where the Austin chalk is exposed; but the Taylor marl (equal in age to the Anacacho limestone), is mapped not far away. The locality given by Roemer may be regional rather than specific, and the type may have come from the Taylor marl rather than from the Austin chalk.

Hemiaster sabinal Cooke, n. sp.

Plate 13, figures 7–10

Test large; upper surface high, highest point on the posterior keel, and a broad, gently sloping posterior truncation; lower surface rounded, with a transverse furrow passing across the peristome and a deep, rounded furrow extending from the peristome through the

anterior ambulacrum to the apical system and indenting the margin; anterior end geniculated, the geniculation increased by crushing. Apical system probably in front of the center. Paired petals deeply sunken; anterior pair straight, widely spreading, long; posterior pair somewhat shorter, curved backward, not widely spreading; pores elongated, conjugate. Pores of anterior ambulacrum small, round, separated by a bead. Peristome not far forward, transversely elongated, with anterior sides nearly straight, with a high, narrow lip behind. Periproct longitudinally elongated, high up on the posterior slope, plainly visible from above. Peripetalous fasciole strongly indented between the lateral petals.

Length of type (a crushed specimen) 70 mm; width 67 mm; height 37 mm.

Occurrence.—Texas: Sabinal River at Dillard's ranch house, Uvalde quadrangle (U.S.G.S. 1873, T. W. Vaughan).

Geologic horizon.—Austin chalk, of Coniacian or Santonian age.

Type.—U.S.N.M. 108400.

Comparison.—*Hemiaster sabinal* is much larger than *H. texanus* Roemer, which has a central apical system, straight posterior petals, a steeper posterior slope, and a fasciole without indentations.

Hemiaster ungula (Morton)

Plate 14, figures 10–14

Spatangus ungula Morton, 1833, Am. Jour. Sci., ser. 1, vol. 24, p. 131, pl. 10, fig. 6.

Spatangus ungula Morton. Morton, 1834, Synopsis of the organic remains of the Cretaceous group, p. 78, pl. 10, fig. 6.

Micraster ungula (Morton). Agassiz in Agassiz and Desor, 1847, Catalogue raisonné des échinodermes (reprint), p. 141.

Holaster ungula (Morton). Gabb, 1859, Cat. invert. foss. Cretaceous, p. 19.

Not *Hemiaster ungula* (Morton). Clark, 1891, Johns Hopkins Univ. Circ., vol. 10, no. 87, p. 77.

Not *Hemiaster ungula* (Morton). Clark, 1893, U. S. Geol. Survey Bull. 97, p. 88, pl. 46, figs. 2a–g.

Not *Hemiaster ungula* (Morton). Clark, 1915, U. S. Geol. Survey, Mon. 54, p. 93, pl. 48, figs. 3a–g.

Not *Hemiaster* (*Gregoryaster*) *ungula* (Morton). Lambert and Thiéry, 1924, Nomenclature raisonnée des échinides, fasc. 7, p. 503.

Horizontal outline cordate, with a weak frontal furrow vertically truncated behind. Petals sunken. Anterior paired petals extending more than halfway to the margin, diverging at an angle of nearly 90°. Posterior petals shorter, less diverging. Peristome transversely oval, apparently strongly lipped. Periproct oval, well up on the posterior truncation.

Occurrence.—Delaware: Delaware and Chesapeake Canal.

Geologic horizon.—Upper Cretaceous, formation unknown.

Type.—Acad. Nat. Sci. Philadelphia 1503.

Remarks.—This species is based on a cast of the interior, which is somewhat crushed and partly broken. Clark's drawings (1893, pl. 46, figs. 2a–g; 1915, pl. 48, figs. 3a–g), which ostensibly repre-

sent the type, probably were made from specimens of an Eocene species from Vincentown, N. J., in the Philadelphia Academy (no. 1502).

"Hemiaster" kummeli Clark

Plate 13, figures 5, 6

Hemiaster kummeli Clark, 1907, New Jersey Geol. Survey, Paleontology ser., vol. 4, p. 303, pl. 17, figs. 1-3.

Hemiaster kummeli Clark. Clark, 1915, U. S. Geol. Survey Mon. 54, p. 97, pl. 52, figs. 1-3.

This species is based on a badly crushed cast of the interior with rather long posterior petals much like those of *Hemiaster texanus* Roemer. It is unrecognizable without better-preserved topotypes.

Occurrence.—New Jersey: Lorillard clay pits near Keyport.

Geologic horizon.—Woodbury clay, of Campanian age.

Type.—New Jersey State Museum.

Hemiaster delawarensis Clark

Plate 14, figures 6-9

Hemiaster delawarensis Clark, 1916, Maryland Geol. Survey, Upper Cretaceous, p. 751, pl. 47, figs. 11-14.

This species, known only from the type, is described by Clark as follows:

Test small, nearly circular, slightly cordiform, truncated posteriorly; upper surface slightly convex, elevated posteriorly; lower surface nearly flat; sides inflated; apex nearly central, slightly posterior of the center; ambulacra slightly depressed, posterior pair short, anterior surface broad. Peristome slightly depressed. Periproct small, high above posterior margin. Peripetalous fasciole narrow, distinct.

Length 22 mm.; width 22 mm.; height 17 mm.

Occurrence.—Delaware: Marl pit south side of Delaware and Chesapeake Canal, 1 mile east of St. Georges.

Geologic horizon.—Probably from the Mount Laurel sand (Clark says Matawan formation).

Type.—Johns Hopkins University (*vide* Clark).

Hemiaster welleri Clark

Plate 14, figures 15-17

Hemiaster welleri Clark, 1907, New Jersey Geol. Survey, Paleontology series, vol. 4, p. 302, pl. 17, figs. 4-6.

Hemiaster welleri Clark. Clark, 1915, U. S. Geol. Survey Mon. 54, p. 98, pl. 52, figs. 2a-c.

Hemiaster (Integraster) welleri Clark. Lambert and Thiéry, 1924, Nomenclature raisonnée des échinides, fasc. 6, p. 504.

This species is based on a broken cast of the interior, which lacks the apical system and the posterior petals. It is unrecognizable without better-preserved topotypes. In general appearance it resembles *Hemiaster wetherbyi* de Loriol and *H. arcolensis* Cooke, both of which occupy higher horizons in Alabama.

Occurrence.—New Jersey: Railroad cut 1 mile south of Lower Jamesburg.

Geologic horizon.—Merchantville clay, of Santonian age.

Type.—New Jersey State Museum.

Hemiaster amelianus Cooke, n. sp.

Plate 16, figure 1

Horizontal outline subovate, with a shallow frontal depression; upper surface rather flat, with a conspicuous posterior keel; margin rounded. Apical system behind the center. Petals depressed; anterior petal unlike the others, pores close together, separated by a raised bead; anterior paired petals long, slightly flexuous at the ends, not widely spreading; posterior paired petals much shorter, nearly in line with the anterior pair, the two forming an X; pores of paired petals moderately elongated, separated by their own length. Peripetalous fasciole not at all indented. Peristome and periproct unknown.

Length 30 mm; width 28.5 mm.

Occurrence.—Guatemala: Airstrip near the Rio de la Pasion at Santa Amelia, Peten (U.S.N.M. accession 195206, Barnum Brown).

Geologic horizon.—Campanian?

Type.—U.S.N.M. 108408.

Comparison.—*Hemiaster amelianus* is suggestive of *H. humphreysanus* Meek and Hayden, but its posterior petals are much less widely spreading.

Genus LINTHIA Desor

Linthia Desor, 1853, Soc. helvétique sci. nat. Actes (Porrentruy) (Schweizer. naturf. Gesell. Verh.), p. 278.

Linthia Merian. Desor, 1858, Synopsis des échinides fossiles, p. 395.

Linthia Merian. Cotteau, 1886, Paléontologie française, Terrain tertiaire, ser. 1, tome 1, p. 206.

Linthia Desor. Gardner, 1935, Texas Univ. Bull. 3301, p. 109.

Schizaster (Linthia) Desor. Cooke, 1942, Jour. Paleontology, vol. 16, no. 1, p. 41.

Linthia Desor. Mortensen, 1951, Monograph of the Echinoidea, vol. 5, pt. 2, p. 233. (Gives additional synonymy.)

Type species *Escheria insignis* Merian, designated by Desor (1855-1858, p. 395). This Eocene species has been figured by Desor (1855-1858, p. 395, pl. 43, fig. 9), Cotteau (1885-1889, p. 232, pl. 70), and by Mortensen (1951, p. 235, fig. 116), who copies Desor's figure.

Linthia insignis is a large species, with central apical system, which is broken in the type; long, straight sunken petals, the anterior pair longer and more widely spreading than the posterior pair; moderately sunken anterior ambulacrum; a peripetalous fasciole, which is deeply indented in all interambulacral areas; and lateral fascioles.

Linthia differs from *Schizaster*, to which it was referred as a subgenus by Cooke (1942, p. 41) in its central apical system, its straight petals, and its longer posterior petals. It resembles *Schizaster* in its complement of fascioles and in its apical system, which is plainly ethmolytic in all the species known to me. It

resembles *Hemiaster* in many features but differs from than genus in the presence of lateral fascioles. Moreover, the apical system of many species of *Hemiaster* is ethmophratic.

Linthia variabilis Slocum

Plate 14, figures 18-25

Linthia variabilis Slocum, 1909, Field Mus. Nat. History, Geol. Ser., vol. 4, no. 1, p. 12, text fig. 1a-c; pl. 3, figs. 1-11.

Linthia variabilis Slocum. Clark, 1915, U. S. Geol. Survey Mon. 54, p. 99, pl. 54, figs. 1a-1.

Linthia variabilis Slocum. Stephenson, 1927, U. S. Natl. Mus. Proc., vol. 72, no. 2706, p. 10, pl. 5, figs. 1-7.

Linthia variabilis Slocum. Stephenson and Monroe, 1940, Mississippi Geol. Survey Bull. 40, p. 280, pl. 10, figs. 1-5.

Linthia variabilis Slocum? Stephenson, 1941, Texas Univ. Bull. 4101, p. 68, pl. 8, figs. 1-5.

Linthia variabilis Slocum. Sanchez Roig, 1949, Paleontologia Cubana I, p. 268.

Test cordate, vertically truncated behind; vertical profile highest behind the apical system. Apical system behind the center, having only four genital plates, all perforated, the lateral plates in contact; posterior ocular plates separated by the madreporite, which extends beyond them. Anterior ambulacrum sunken, subpetaloid, the pores small, round, pores of each pair within the peripetalous fasciole separated by a small bead. Paired petals straight, deeply sunken; pores oval or slightly elongated, conjugate; poriferous zones wider than interporiferous zones; anterior petals about twice as long as posterior pair, less widely spreading. Peristome far forward, sunken, strongly labiate behind. Periproct large, higher than wide, at the top of the posterior truncation, scarcely visible from above. Peripetalous fasciole deeply indented between the lateral petals; lateral fascioles meeting below the periproct. Basal part of posterior ambulacra having a shagreened surface; remainder of base covered with large tubercles on scaly socles; tubercles on upper surface much smaller and crowded.

Length of figured specimen 24.2 mm; width 24.4 mm; height 18.5 mm.

Occurrence.—Mississippi: One Mile Run, south edge of Pontotoc, on the Houston road (type, A. W. Slocum; U.S.G.S. 6470, 6852, L. W. Stephenson; U.S.G.S. 11652, L. W. Stephenson and C. W. Cooke; 17206, L. W. Stephenson and W. H. Monroe). Southwest edge of Pontotoc (U.S.G.S. 6853, L. W. Stephenson). One mile east of Pontotoc (U.S.G.S. 6855, L. W. Stephenson). Owl Creek, 2¾ miles northeast of Ripley (U.S.G.S. 8309, E. N. Lowe). Wallerville, Union County (U.S.G.S. 9604, L. W. Stephenson and Bruce Wade). Route 15, sec. 16, T 6 S, R 3 E, Union County (U.S.G.S. 18077, W. H. Monroe).

North Carolina: West side of Hilton Park, Northeast Cape Fear River (U.S.G.S. 4143, L. W. Stephenson).

Arkansas: High bluff on Ouachita River 1.5 miles above Arkadelphia (U.S.G.S. 13541, L. W. Stephenson and C. H. Dane).

Texas: Six miles east of Castroville (U.S.G.S. 16156, L. W. Stephenson); Hill south of Seguin-San Antonio highway 2.5

miles west of McQueeney, Guadalupe County (U.S.G.S. 15523, L. W. Stephenson).

Geologic horizon.—Prairie Bluff chalk in Mississippi, Peedee formation in North Carolina, Nacatoch sand in Arkansas, Corsicana marl in Texas; all of late Senonian (Maestrichtian) age.

Types.—Chicago Natural History Museum, type of *L. variabilis*. Figured specimens: U.S.N.M. 76251 (Stephenson and Monroe, 1940); U.S.N.M. 76283, 76284 (Stephenson, 1941); U.S.N.M. 73448 (pl. 14, figs. 18-21); U.S.N.M. 108401 (pl. 14, figs. 22-25).

Genus PRORASTER Lambert

Proraster Lambert, 1895, Carte géol. det. de la France Mém., Recherches sur la craie supérieure, pt. 1, chap. 4, p. 256.

Proraster Lambert. Lambert, 1907, Soc. géol. France Mém., tome 14, p. 103.

Hemiaster (*Proraster*) Lambert. Lambert and Thiéry, 1924, Nomenclature raisonnée des échinides, fasc. 6, p. 506.

Hemiaster (*Proraster*) Lambert. Lambert, 1927, Museo Ciencias Nat. Barcelona Mem., ser. geol., vol. 1, no. 1, p. 51.

Proraster Lambert. Adkins, 1928, Texas Univ. Bull. 2838, p. 299.

Proraster Lambert. Mortensen, 1951, Monograph of the Echinoidea, vol. 5, pt. 2, p. 228.

Type species *Schizaster atavus* Arnaud, by elimination. As originally described, *Proraster* included two other species, *Spatangus lacunosus* Goldfuss (not Leske) and *Schizaster antiquus* Cotteau, but these two have lateral fascioles, which fact excludes them from *Proraster* (Lambert and Thiéry, 1909-1925, p. 506).

Proraster atavus (Arnaud) was originally described in Cotteau (1883, p. 179, pl. 12, figs. 5-10), whose figures show short sunken posterior petals, long flexuous anterior paired petals, a deeply sunken anterior ambulacrum, which strongly indents the margin, four equally spaced genital pores. The madreporite extends backward and barely separates the posterior oculars. The peristome is far forward, strongly labiate behind. A peripetalous fasciole is barely indented. The periproct is well up on a posterior vertical truncation. The flexuous petals and the deep anterior depression resemble *Schizaster*, but the species lacks lateral fascioles. Mortensen (1951, p. 229, fig. 110) copied three of Arnaud's figures, and Lambert (1927, p. 50, pl. 3, fig. 23) figures a specimen from Spain.

***Proraster dalli* (Clark)**

Plate 15, figures 1-5

Hemiaster dalli Clark, 1891, Johns Hopkins Univ. Circ., vol. 10 no. 87, p. 77.

Hemiaster dalli Clark. Clark, 1893, Johns Hopkins Univ. Circ. vol. 12, no. 103, p. 52.

Hemiaster dalli Clark. Clark, 1893, U. S. Geol. Survey Bull. 97, p. 89, pl. 48, figs. 2a-e.

Hemiaster dalli Clark. Clark, 1915, U. S. Geol. Survey Mon. 54, p. 90, pl. 47, figs. 1a-f.

Hemiaster (*Proraster*) *dalli* Clark. Lambert and Thiéry, 1924, Nomenclature raisonnée des échinides, fasc. 6, p. 506.

Proraster dalli (Clark). Lambert, 1926, Soc. géol. France Bull., ser. 4, t. 26, p. 273.

Proraster dalli (Clark). Adkins, 1928, Texas Univ. Bull. 2838, p. 300.

Hemiaster dalli Clark. Stephenson, 1941, Texas Univ. Bull. 4101, p. 63, pl. 6, figs. 1-4.

Horizontal outline cordiform, deeply indented in front, truncated behind; longitudinal profile highest behind the apical center, thence sloping steeply backward to the vertical truncation, and more gently forward. Lower surface moderately tumid. Apical system well back of the center; four genital pores, the side two very close together and very far away from the other pair; ethmolytic, the madreporite extending between and far beyond the posterior oculars. Anterior ambulacrum deeply excavated, the depression extending to the peristome; zygopores short, the pores round or oval, separated by a small bead. Paired petals deeply excavated, the forward pair about twice as long as the rear pair; anterior petals bent forward near the apex, flaring slightly outward near the distal ends; posterior petals straight, diverging at an angle of about 70°. Peristome sunken, covered by a strongly arched posterior lip. Periproct longitudinally oval; high up on the posterior truncation.

Length of figured specimen from U.S.G.S. 17990 33.1 mm; width 31.1 mm; height 21.5 mm.

Occurrence.—Texas: *Anacacho limestone*.—Bexar County (type). Grosebacher road 1 mile south of the Potranca road, Bexar County (U.S.G.S. 16465, A. N. Sayre). Grosebacher road, Bexar County, 1.2 miles southeast of Potranca School (U.S.G.S. 17990, A. N. Sayre). *Anacacho* (U.S.G.S. 16765, J. A. Udden). Rio Medina at Siphon No. 2, 4 miles north-northwest of Rio Medina, Medina County (U.S.G.S. 12904, L. W. Stephenson). Left bank Nueces River 0.3 mile above the Southern Pacific Railway bridge, Uvalde County (U.S.G.S. 15340, L. W. Stephenson and party).

Corsicana marl.—Cut on San Antonio road 6 miles east of Castroville (U.S.G.S. 15502, L. W. Stephenson). Earth tank just north of Castroville road 1.2 miles west of crossing of Leon Creek, Bexar County (U.S.G.S. 15522, L. W. Stephenson).

Geologic horizon.—*Anacacho limestone* (of Campanian age) and *Corsicana marl* (Maestrichtian).

Type.—U.S.N.M. 19114; specimen figured by Stephenson U.S.N.M. 76280, from U.S.G.S. 15502; specimens figured herein U.S.N.M. 108402, 108403, from U.S.G.S. 17990, 12904.

Remarks.—The specimens from the *Corsicana marl* are smaller than those from the *Anacacho limestone*, and their posterior petals seem to be a trifle more diverging.

Genus MICRASTER Agassiz

Micraster Agassiz, 1836, Soc. sci. nat. Neuchâtel Mém., t. 1, p. 184.

Micraster Agassiz. Agassiz 1839, Allg. schweizerischen Gesell. gasammten Naturw. neue Denkschr., Band 3, (art. 3) p. 25.

Micraster Agassiz, 1840, Catalogus ectyporum Echinodermatum fossilium, p. 15.

Micraster Agassiz. Agassiz and Desor, 1847, Catalogue raisonné des échinodermes, p. 129.

Micraster Agassiz. D'Orbigny, 1855, Paléontologie française, Terrain crétacé, ser. 1, tome 6, p. 201.

Micraster Agassiz. Desor, 1858, Synopsis des échinides fossiles p. 360.

Micraster Agassiz. Cotteau and Triger, 1869, Échinides du département de la Sarthe, p. 432.

Micraster D'Orbigny. De Loriol, 1873, Échinologie helvétique, pt. 2, p. 368.

Micraster Agassiz. Wright, 1878, British fossil Echinodermata from the Cretaceous formations, p. 270.

Micraster Agassiz. Pomel, 1883, Classification méthodique et genera des échinides, p. 42.

Micraster Agassiz. Duncan, 1889, Linnean Soc. London Jour., Zoology, vol. 23, p. 240.

Micraster Agassiz. Lambert, 1895, in Grossouvre, Recherches sur la craie supérieure, p. 150.

Micraster Agassiz. Savin, 1903, Soc. d'histoire nat. de Savoie Bull., tome 8, p. 79.

Micraster Agassiz. Mortensen, 1950, Monograph of the Echinoidea, vol. 5, pt. 1, p. 364. Gives additional synonymy.

Type species *Spatangus coranguinum* Leske (1778, p. 221, pl. 23, figs. C, D), designated by Pomel, from the White Chalk of England. This well-known species has been figured by Wright (1864-1882, p. 271, pl. 62). Characteristics are its central, plainly ethmophract apical system; its short anterior petal with small round pores separated by a bead; its straight paired petals with oval or slightly elongated pores; its anterior, strongly lipped peristome; its periproct high on a posterior vertical truncation; and its subanal fasciole. Some species admitted to the genus show "a trace of a pseudo-semi-peripetalous fasciole" (Smiser, 1935, p. 80).

Two American species have heretofore been referred to *Micraster*. One of these, though not typical, is retained in the genus; the other, "*Micraster*" *elevatus* Sanchez Roig (1949, p. 218, pl. 47, figs. 4, 5), cannot represent *Micraster* because it has well-defined peripetalous and marginal fascioles but apparently no subanal fasciole.

Micraster uddeni Cooke, n. sp.

Plate 15, figures 6-9

Test cordate, with a deep, narrow sulcus extending from the apex to the peristome. Apical system slightly posterior, ethmophract, with four genital pores, posterior ocular plates large, in contact. Petals sunken, straight, the anterior pair twice as long as and slightly more widely spreading than the posterior pair; pores of paired petals elongate, poriferous zones equalling the interporiferous; pores of anterior ambulacrum in echelon, separated by a small bead, zones much narrower than the interporiferous. Peristome far forward. Periproct terminal, about halfway up the posterior truncation. Subanal fasciole partly preserved.

Length 59 mm; width 60 mm; height about 32 mm.

Occurrence.—Texas: Tequesquite Creek, Maverick County, (U.S.G.S. 16768, J. A. Udden).

Geologic horizon.—Austin chalk, of Santonian age.

Type.—U.S.N.M. 108404.

Comparisons.—This species is flatter and has longer petals

than *Micraster coranguinum* (Leske). It is proportionately shorter and wider than *M. americanus* Stephenson, and its posterior petals are shorter.

***Micraster americanus* Stephenson**

Plate 15, figures 10-13

Micraster (Plesiaster) americanus Stephenson, 1941, Texas Univ. Bull. 4101, p. 69, pl. 7, figs. 1-4.

Test subcordate, higher behind than in front, with rounded lateral and anterior margins, truncated behind. Apical system slightly behind the center, ethmophract, with four genital pores. Anterior ambulacrum broadly depressed, the depression extending to the peristome and indenting the margin; petaliferous part extending about halfway to the margin, zygopores inclined, divided by a bead; pores small, round. Paired petals depressed, extending more than halfway to the margin; anterior pair the longer, nearly straight, widely diverging; posterior pair slightly curved backward; pores elongate-oval, similar in all zones; poriferous zones somewhat narrower than interporiferous zones. Peristome at the anterior third, surrounded by a rim; strongly lipped behind. Periproct vertically elongated, small, well up on a vertical posterior truncation, barely visible from above. Subanal fasciole complete; peripetalous fasciole extending around the paired petals but indistinct or wanting at the anterior end. Tubercles crenulated, perforated.

Length of holotype 30 mm; width 26.5 mm; height 19.5 mm.

Occurrence.—Texas: 6 miles east of Castroville, cut in San Antonio road in Bexar County (U.S.G.S. 15502, type, L. W. Stephenson). San Geronimo Creek about 2 miles below Cliff, 10 miles northeast of Castroville, Medina County (U.S.G.S. 10870, L. W. Stephenson).

Arkansas: Ozan road 3.1 miles north of Washington, Hempstead County (U.S.G.S. 13408, L. W. Stephenson). Okolona road about 7.5 miles southwest of Arkadelphia, Clark County (U.S.G.S. 13406, L. W. Stephenson and C. H. Dane). Gullies north of Okolona road 7.4 miles southwest of Arkadelphia (U.S.G.S. 13537, L. W. Stephenson). Road cut at north edge of Saratoga (U.S.G.S. 13404, L. W. Stephenson). Columbus road ¼ mile east of Saratoga (U.S.G.S. 9732, L. W. Stephenson). Big Deciper Creek 5 miles southwest of Arkadelphia on the road to Okolona (U.S.G.S. 7460, L. W. Stephenson). Big Deciper Creek below the lower Okolona road where road to Curtis and Gurdon forks to left, 5.4 miles southwest of Arkadelphia (U.S.G.S. 13539, L. W. Stephenson).

Mississippi: Wallerville, Union County (U.S.G.S. 9604, L. W. Stephenson and Bruce Wade). Southwest edge of Pontotoc near the embankment of M. J. & K. C. Ry. (U.S.G.S. 6853, L. W. Stephenson). Troy-Shannon road 0.25 mile east of Troy, Pontotoc County (U.S.G.S. 6471, L. W. Stephenson).

Geologic horizon.—Corsicana marl (Texas); Saratoga chalk (Arkansas); Prairie Bluff chalk (Mississippi); Ripley formation (Mississippi, U.S.G.S. 6471); all of Maestrichtian age.

Type.—U.S.N.M. 76285. Figured specimen U.S.N.M. 108405, from U.S.G.S. 13404.

Remarks.—The specimens from Arkansas are nearly twice as

large as the type but resemble it in other features. Those from Mississippi are intermediate in size.

Micraster americanus differs from the type species, *Micraster coranguinum*, in having a fairly distinct partial peripetalous fasciole, but in other generic features they seem closely related. This difference can scarcely be of greater than subgeneric rank.

Micraster americanus was referred to *Plesiaster* as a subgenus by Stephenson, but the type of *Plesiaster peini* (Coquand) as figured by Gauthier (Mortensen, 1951, p. 368, fig. 174) has pores in its odd ambulacrum like those of the paired petals. The American species may be more like *Diplodetus*, which, however, has a complete peripetalous fasciole. Both *Plesiaster* and *Diplodetus* are treated as genera in the Brissidae by Mortensen (1951, pp. 368, 370). Both, however, are said (Mortensen, 1951, p. 355) to have ethmophractic apical systems in contrast to the ethmolytic system of *Brissus*, in which the madreporite extends between the posterior ocular plates. This seems ample reason for excluding them from the Brissidae.

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<i>requienii</i>	17
<i>wilderae</i>	17, 18
<i>Nucleopygus</i>	12, 17
<i>minor</i>	13
<i>texanus</i>	3, 13, pl. 4
<i>Nucleopyrina</i>	11
<i>nucleus</i> , <i>Globator</i>	12
<i>nucula</i> , <i>Conulus</i>	12
<i>Nuculites</i> <i>scutata</i>	13

O

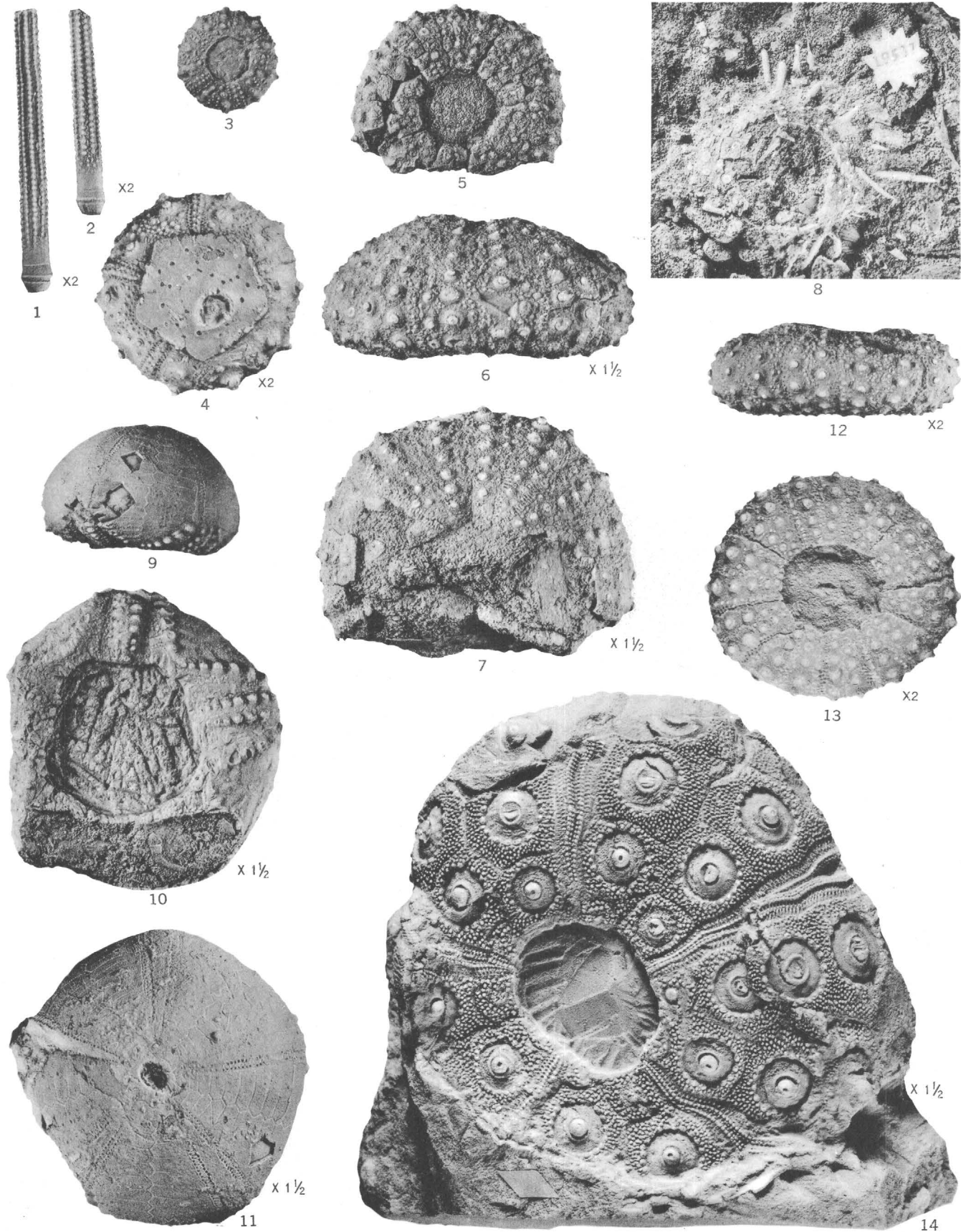
<i>Oolopygus</i>	16
<i>Oolopygus gracilis</i>	16
<i>pyriformis</i>	16
(<i>Oolopygus</i>) <i>williamsi</i> , <i>Catopygus</i>	2, 3, 16, pl. 5
<i>oregonensis</i> , <i>Hemiaster</i>	1
<i>ovata</i> , <i>Ananchytes</i>	25

PLATES 1–16

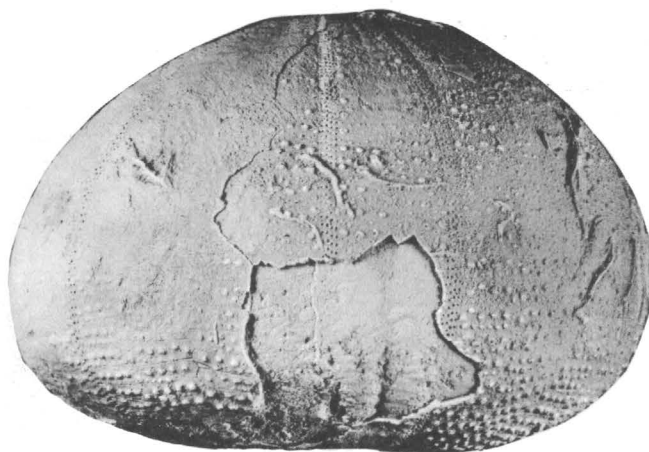
PLATE 1

[All figures natural size except as indicated on plate]

- FIGURES 1, 2. *Cidaris wahalakensis* De Loriol (p. 5).
Spines, U.S.N.M. 108365. From the Prairie Bluff chalk at U.S.G.S. 18143, Sumpter County, Ala.
- 3, 4. *Salenia hondoensis* Cooke, n. sp. (p. 6).
Holotype, U.S.N.M. 108366. From the Anacacho limestone at U.S.G.S. 12902, King's water hole, 3 miles west of Hondo, Tex.
- 5-8. *Porosoma reesidei* Cooke, n. sp. (p. 6).
5-7, Bottom side, and top of holotype, U.S.N.M. 108367, from U.S.G.S. 23423.
8, Top of paratype, U.S.N.M. 108368, from U.S.G.S. 19537, showing spines. Both from the top of the Frontier formation in NE $\frac{1}{4}$ sec. 1, T 42 N, R 107 W, Fremont County, Wyo.
- 9-11. *Codiopsis stephensoni* Cooke, n. sp. (p. 8).
From the lower part of the Escondido formation at U.S.G.S. 15347, Nueces River, Uvalde County, Tex.
- 12, 13. *Rachiosoma mortoni* (De Loriol) (p. 9).
Side and bottom of U.S.N.M. 108370. From the Ripley formation at U.S.G.S. 850, Chattahoochee River below Eufaula, Ala.
14. *Cidaris texanus* Clark (p. 5).
Holotype, U.S.N.M. 8381. Possibly from the Anacacho limestone in Bexar County, Tex.



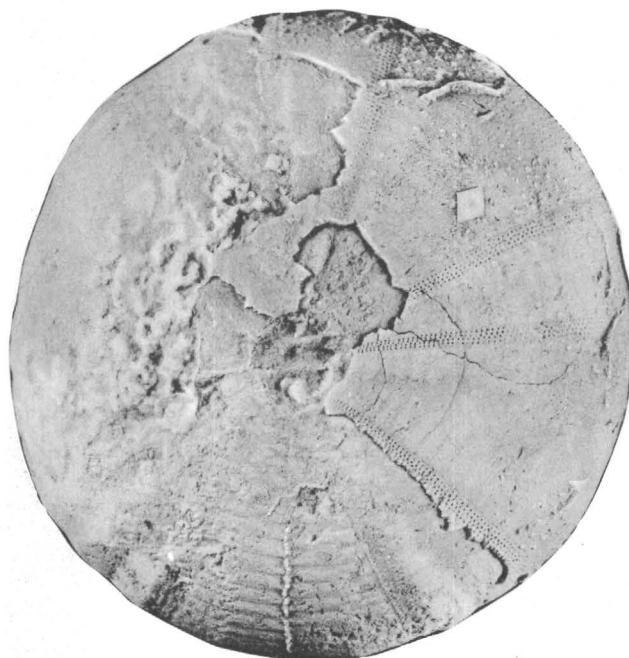
CIDARIS, SALENIA, POROSOMA, CODIOPSIS, AND RACHIOSOMA



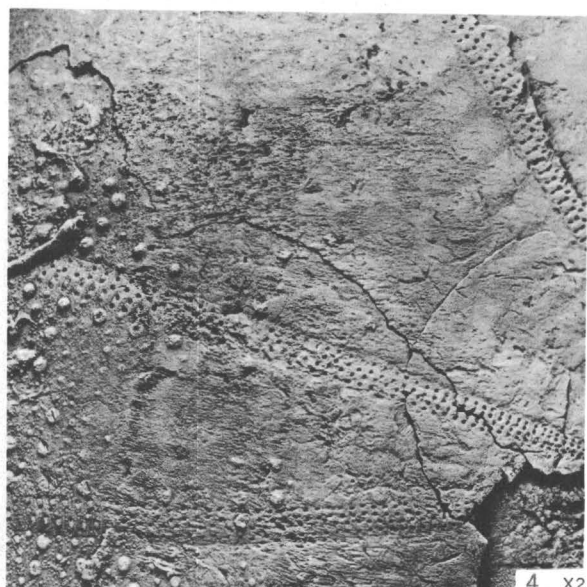
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PEDINOPSIS

PLATE 2

[All figures natural size except as indicated on plate]

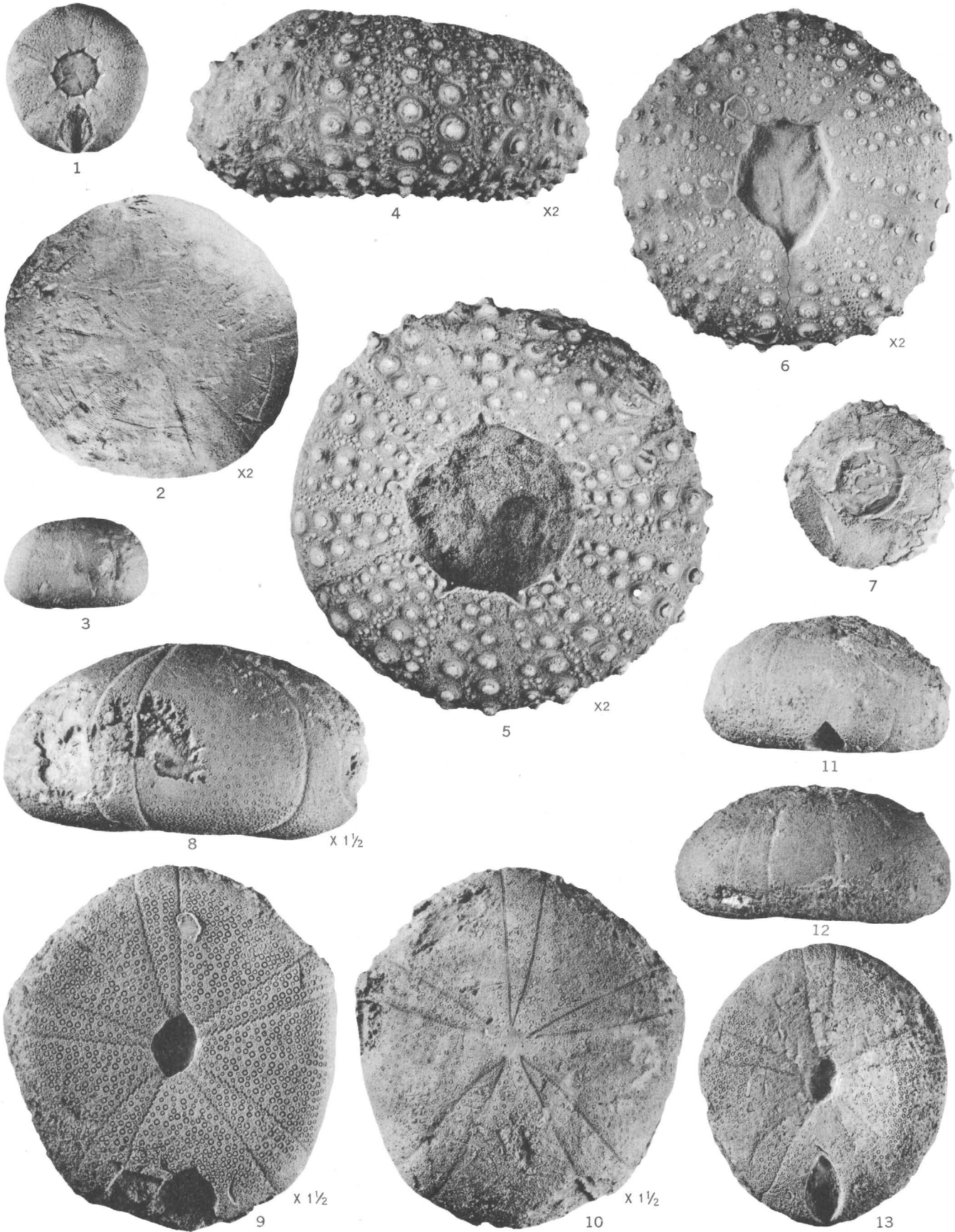
FIGURES 1-5. *Pedinopsis pondi* Clark (p. 7).

Side, bottom, top, and parts of the upper and lower surfaces of holotype, U.S.N.M 103707. From the Austin chalk in Travis County, Tex.

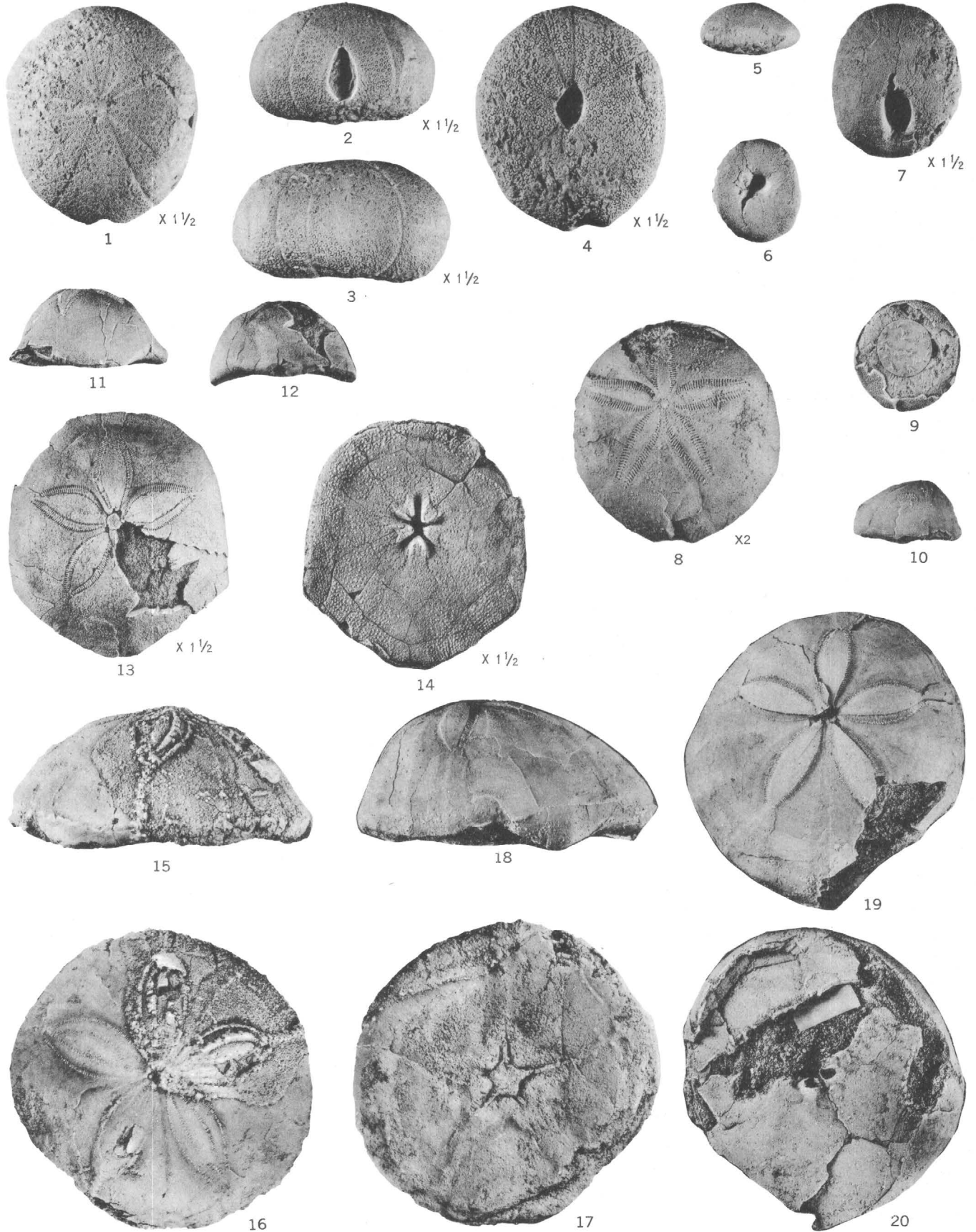
PLATE 3

[All figures natural size except as indicated on plate]

- FIGURES 1-3. *Lanieria uvaldana* Cooke, n. sp. (p. 10).
Bottom, top, and side of holotype, U.S.N.M. 108372. Probably from the Anacacho limestone at U.S.G.S. 1771, Turkey Creek at Carbonville, Uvalde County, Tex.
- 4, 5. *Rachiosoma hondoensis* Cooke, n. sp. (p. 8).
Side and bottom of holotype, U.S.N.M. 108371. From the Escondido formation at U.S.G.S. 7686, Blue Water Hole, Hondo Creek, Medina County, Tex.
- 6, 7. *Phyosoma hilli* (Clark) (p. 9).
Top and bottom of the largest of three cotypes, U.S.N.M. 8311. From Bell County, Tex., formation unknown.
- 8-13. *Convulus stephensoni* Cooke, n. sp. (p. 11).
8-10, Left side, bottom, and top of holotype, U.S.N.M. 108373, from U.S.G.S. 15626. From the Austin chalk 1 mile northeast of Padrone Hill, Bexar County, Tex.
11-13, Posterior end, left side, and bottom of paratype, U.S.N.M. 108374, from U.S.G.S. 16880. From the Austin chalk on the south side of the valley of Medio Creek, 13 miles west of San Antonio, Tex.



LANIERIA, RACHIOSOMA, PHYMOSOMA, AND CONULUS



GLOBATOR, NUCLEOPYGUS, LEFORTIA, FAUJASIA, AND PYGUROSTOMA

PLATE 4

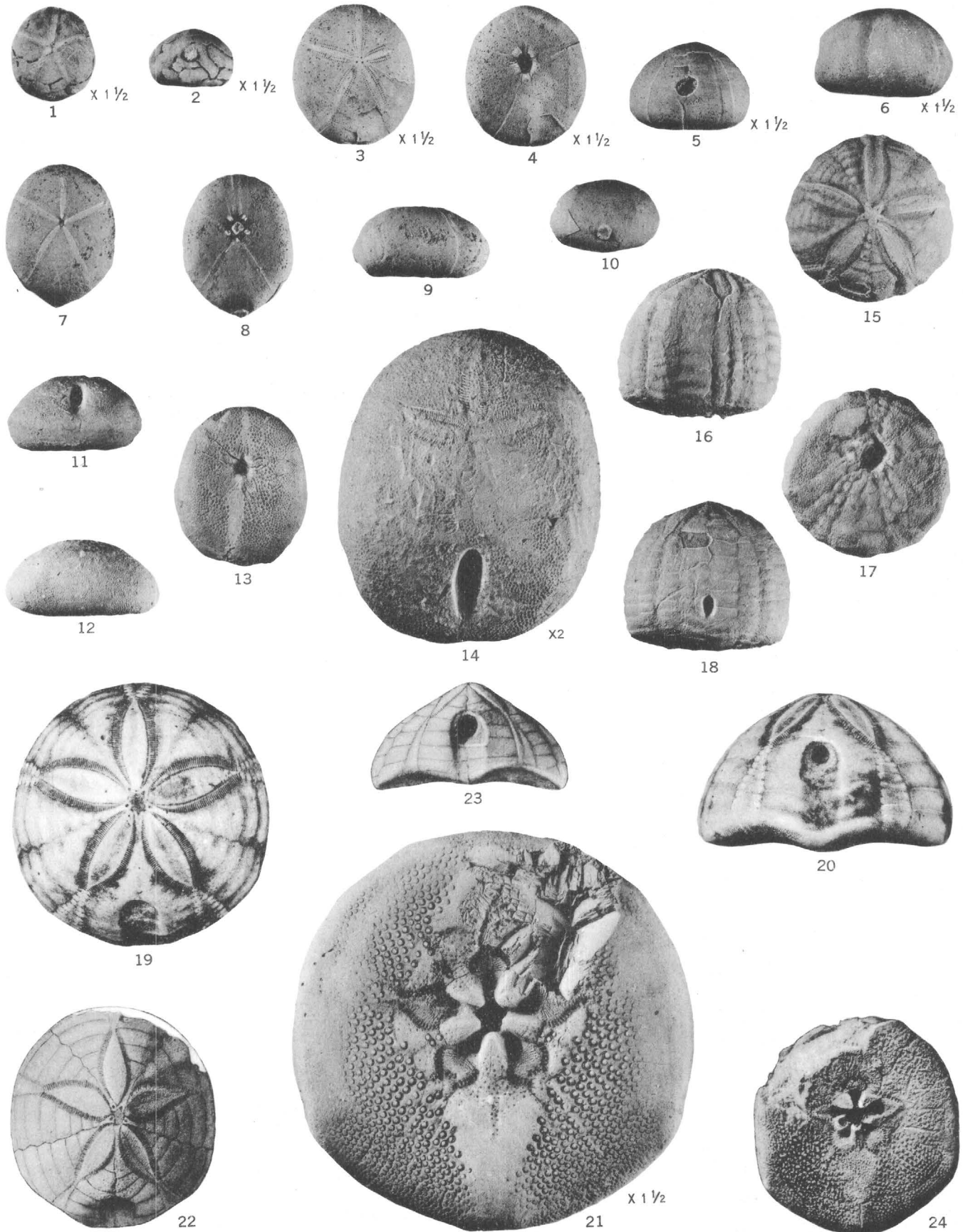
[All figures natural size except as indicated on plate]

- FIGURES 1-4. *Globator vaughani* Cooke, n. sp. (p. 12).
Top, posterior end, left side, and bottom of holotype, U.S.N.M. 108375. From the Anacacho limestone at U.S.G.S. 1771, Carbonville, Uvalde County, Tex.
- 5-7. *Nucleopygus texanus* (Clark) (p. 13).
Left side, bottom, and top of holotype, U.S.N.M. 20266. From the Austin chalk at U.S.G.S. 768, Austin, Tex.
- 8-10. *Lefortia trojana* Cooke, n. sp. (p. 17).
Top, bottom, and right side of holotype, U.S.N.M. 108376. From the Ripley formation at U.S.G.S. 17259, Troy, Miss.
- 11-14. *Faujasia chelonium* Cooke, n. sp. (p. 14).
Left side, posterior end, top, and bottom of holotype, U.S.N.M. 108377. From the Escondido formation at U.S.G.S. 10854, Indio Ranch, Maverick County, Tex.
- 15-20. *Pygurostoma geometricum* (Morton) (p. 14).
15-17, Holotype, Acad. Nat. Sci. Philadelphia 1496, an internal cast, from the Chesapeake and Delaware Canal, Del.
18-20, Top, bottom, and side of U.S.N.M. 108378, from the Marshalltown formation at U.S.G.S. 17753, the Chesapeake and Delaware Canal 2,000 feet east of the railroad bridge, Delaware.

PLATE 5

[All figures natural size except as indicated on plate]

- FIGURES 1, 2. *Catopygus pusillus* Clark (p. 15).
Top and posterior end of type, U.S.N.M. 2210. From the Merchantville clay at Wordills, Monmouth County, N. J.
- 3-6. *Catopygus mississippiensis* Cooke, n. sp. (p. 15).
Top, bottom, posterior end, and right side of holotype, U.S.N.M. 108379. From the Prairie Bluff chalk at U.S.G.S. 6851, 5 miles northeast of Houston, Miss.
- 7-10. *Catopygus williamsi* Clark (p. 16).
Top, bottom, right side, and posterior end of holotype, U.S.N.M. 103698. From the Navesink marl at Atlantic Highlands, N. J.
- 11-14. *Phyllobrissus cubensis* (Weisbord) (p. 17).
Posterior end, left side, bottom, and top of U. S.N.M. 108380. From the Anacacho limestone at U.S.G.S. 22407, northeast of Castroville, Tex.
- 15-18. *Clarkiella hemispherica* (Slocum) (p. 18).
Top, side, bottom, and posterior end of type of *Cassidulus conoideus* Clark, U.S.N.M. 31199. From the Providence sand at the Narrows, Pataula Creek, Georgia.
- 19-21. *Hardouinia mortonis* (Michelin) (p. 19).
Top, posterior end, and bottom of holotype of *Gonioclypeus subangulatus* Emmons, U.S.N.M. 108381. From the Peedee formation in North Carolina.
- 22-24. *Hardouinia mortonis emmonsi* (Stephenson) (p. 20).
Top, posterior end, and bottom of holotype, U.S.N.M. 73423, after Stephenson. From the Peedee formation at U.S.G.S. 12262, 1 mile northeast of Rocky Point, N. C.



CATOPYGUS, PHYLLOBRISUS, CLARKIELLA, AND HARDOUINIA



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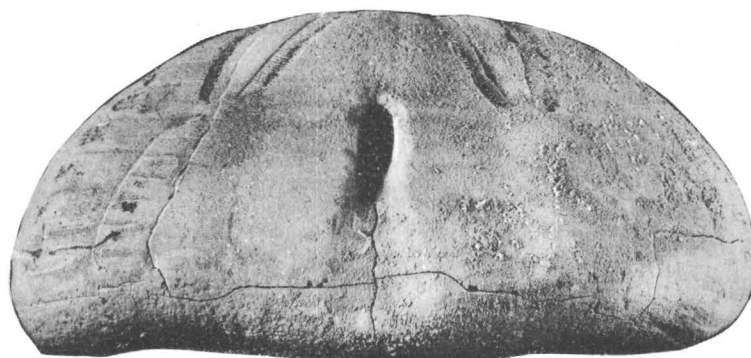


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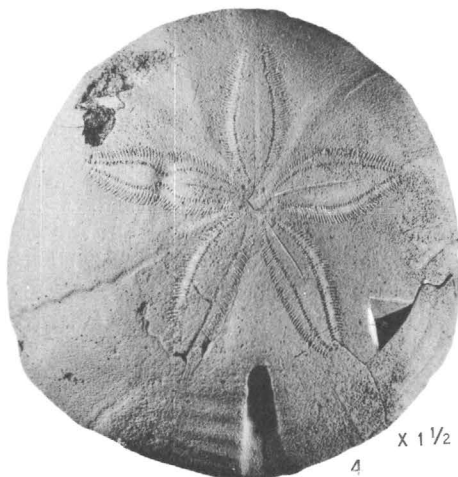


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HARDOUINIA

PLATE 6

[All figures natural size except as indicated on plate]

FIGURES 1-10. *Hardouinia micrococcus* (Gabb) (p. 21).

1-4, Left side, posterior end, bottom, and top of specimen from Barbour County, Ala. Geological Survey of Alabama.

5-8. Top, posterior end, right side, and bottom of cotype, Acad. Nat. Sci. Philadelphia 1480, from Eufaula, Ala.

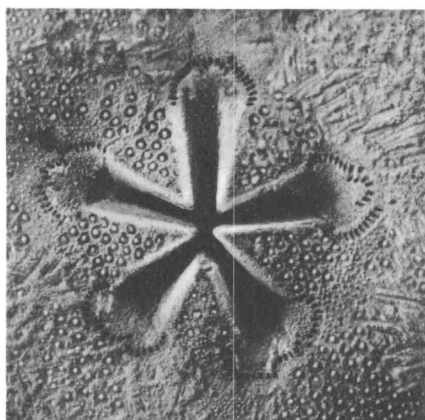
9, 10, Posterior end and top of holotype of *Cassidulus porrectus* Clark, U.S.N.M. 21890, from U.S.G.S. 858, Alexanders Bluff, Chattahoochee River, Ala.

All probably from the Ripley formation.

PLATE 7

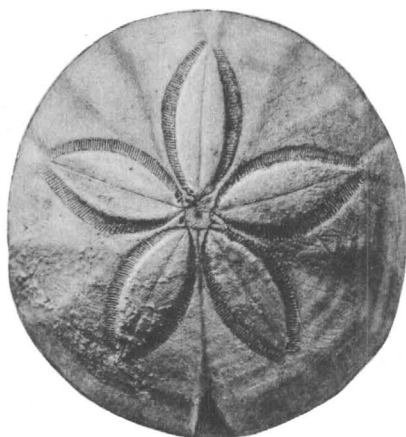
[All figures natural size except as indicated on plate]

- FIGURES 1-5. *Hardouinia kellumi* (Stephenson) (p. 21).
Peristomial region, top, apical region, posterior end, and bottom of holotype, U.S.N.M. 73420. From the Peedee formation at U.S.G.S. 13585, 1 mile northeast of Rocky Point, Pender County, N. C.
- 6-11. *Hardouinia bassleri* (Twitchell) (p. 22).
6, 7, Top and bottom of holotype, U.S.N.M. 9476.
8-11, Top, posterior end, right side, and bottom of U.S.N.M. 108382.
Both from the Tombigbee sand member of the Eutaw formation at U.S.G.S. 17010, Catoma Creek, Montgomery County, Ala.
12. *Hardouinia micrococcus* (Gabb) (p. 21).
Bottom of holotype of *Cassidulus porrectus* Clark, U.S.N.M. 21890.
From the Ripley formation at U.S.G.S. 858, Alexanders Bluff, Chattahoochee River. Ala.

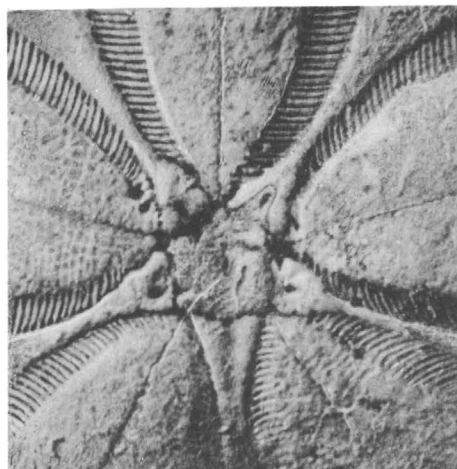


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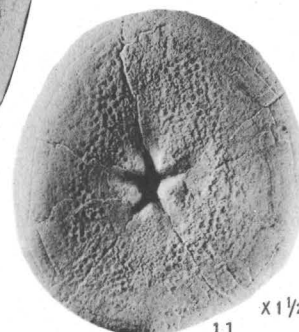


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HARDOUINIA

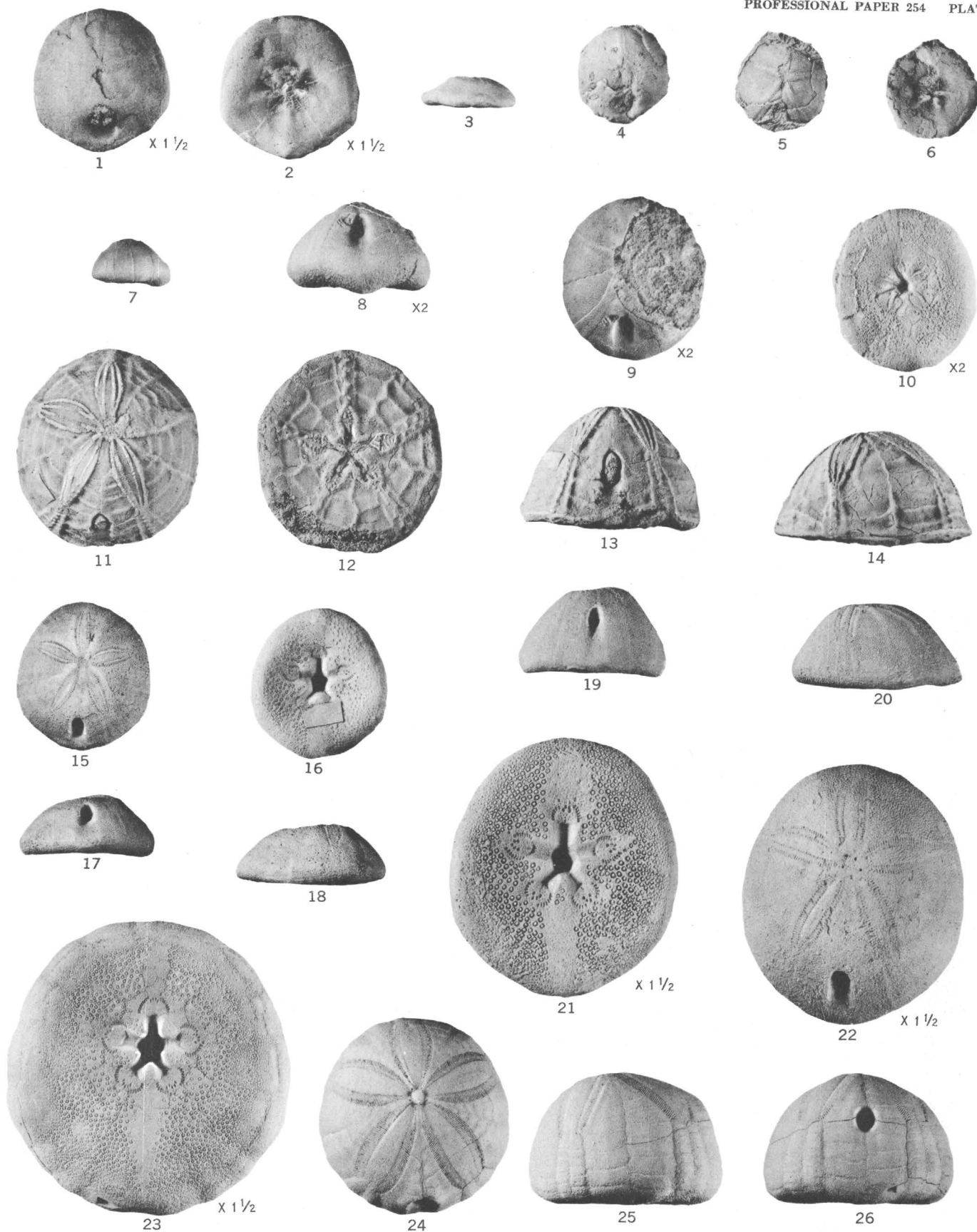


PLATE 8

[All figures natural size except as indicated on plate]

- FIGURES 1-6. *Hardouinia taylori* (Warren) (p. 24).
1-3, Top, bottom, and right side of cotype 301.
4, Top of cotype 302.
5, 6, Top and bottom of cotype 303.
All cotypes Univ. Alberta, Edmonton, Canada. From the Birch Lake sandstone, Birch Lake, Alberta.
- 7-10. *Hardouinia stantoni* (Clark) (p. 23).
Left side, posterior end, top, and bottom of holotype, U.S.N.M. 20268. From the Codell sandstone member of the Carlile shale near Quillian's ranch, Huerfano County, Colo.
- 11-14. *Hardouinia florealis* (Morton) (p. 23).
Top, bottom, posterior end, and left side of type, Acad. Nat. Sci. Philadelphia 1495. From the Delaware and Chesapeake Canal, Del.
- 15-22. *Hardouinia aequorea* (Morton) (p. 22).
15-18, Top, bottom, posterior end, and right side of holotype, Acad. Nat. Sci. Philadelphia 1475, from Prairie Bluff, Ala.
19-22, Posterior end, left side, bottom, and top of U.S.N.M. 108383, from the Prairie Bluff chalk at U.S.G.S 6794, Shell Bluff, Prairie Creek, Ala.
- 23-26. *Hardouinia mcglameryae* Cooke, n. sp. (p. 24).
Bottom, top, left side, and posterior end of holotype, U.S.N.M. 108384. From the Providence sand near Youngblood, Pike County, Ala.

PLATE 9

[All figures natural size except as indicated on the plate]

FIGURES 1-5. *Holaster feralis* Cooke, n. sp. (p. 26).

1-3, Left side, right side, and top of holotype, U.S.N.M. 108385, from Wild Horse Park, 14 miles northwest of Pueblo, Colo.

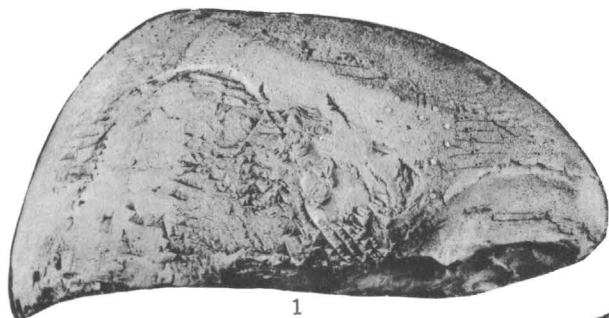
4, 5, Bottom and top of paratype, U.S.N.M. 108386, from U.S.G.S. 22899, Model Dome, Las Animas County, Colo. Both from near the bottom of the type Greenhorn limestone.

6-9. *Pseudananchys stephensoni* Cooke, n. sp. (p. 26).

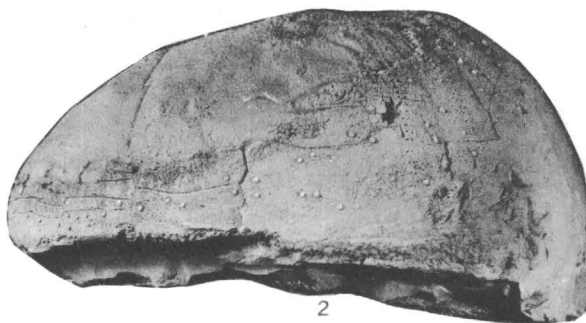
6-8, Left side, top, and bottom of holotype, U.S.N.M. 108387.

9, Bottom of paratype, U.S.N.M. 108387.

Both probably from the Austin chalk at U.S.G.S. 3197, a creek on the Waco-Gholson road, McClennan County, Tex.



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HOLASTER AND PSEUDANANCHYS



ECHINOCORYS, CARDIASTER, AND HOLASTER

PLATE 10

[All figures natural size except as indicated on plate]

- FIGURES 1, 2. *Echinocorys texanus* (Cragin) (p. 25).
Top and bottom of U.S.N.M. 108388. From the Anacacho limestone at U.S.G.S. 12909, Seco Creek 3 miles northwest of D'Hanis, Tex.
- 3-6. *Cardiaster deciper* Cooke, n. sp. (p. 27).
Bottom, top, posterior end, and left side of holotype, U.S.N.M. 108389. From the Saratoga chalk at U.S.G.S. 13539, Big Deciper Creek 5.4 miles southwest of Arkadelphia, Ark.
7. *Holaster feralis* Cooke, n. sp. (p. 26).
Posterior end of paratype, U.S.N.M. 108386. From the bottom of the type Greenhorn limestone at U.S.G.S. 22899, Model Dome, Las Animas County, Colo.

PLATE 11

[All figures natural size except as indicated on plate]

FIGURES 1-7. *Cardiaster leonensis* Stephenson (p. 28).

1-3, Top, bottom, and posterior end of holotype, U.S.N.M. 76279, from the Corsicana marl in Bexar County, Tex.

4-7, Posterior end, bottom, top, and left side of U.S.N.M. 108390, from the Anacacho limestone 2 miles south of Cline, Uvalde County, Tex.

8-10. *Cardiaster smocki* Clark (p. 28).

Top, left side, and bottom of holotype, New Jersey State Museum. From the Merchantville clay 2½ miles northwest of Matawan, N. J.

11-13. *Isomicraster danei* Cooke, n. sp. (p. 29).

Left side, posterior end, and top of holotype, U.S.N.M. 108391. From the Annona chalk at U.S.G.S. 13506, Rocky Comfort, Ark.

14. *Cardiaster curtus* Clark (p. 28).

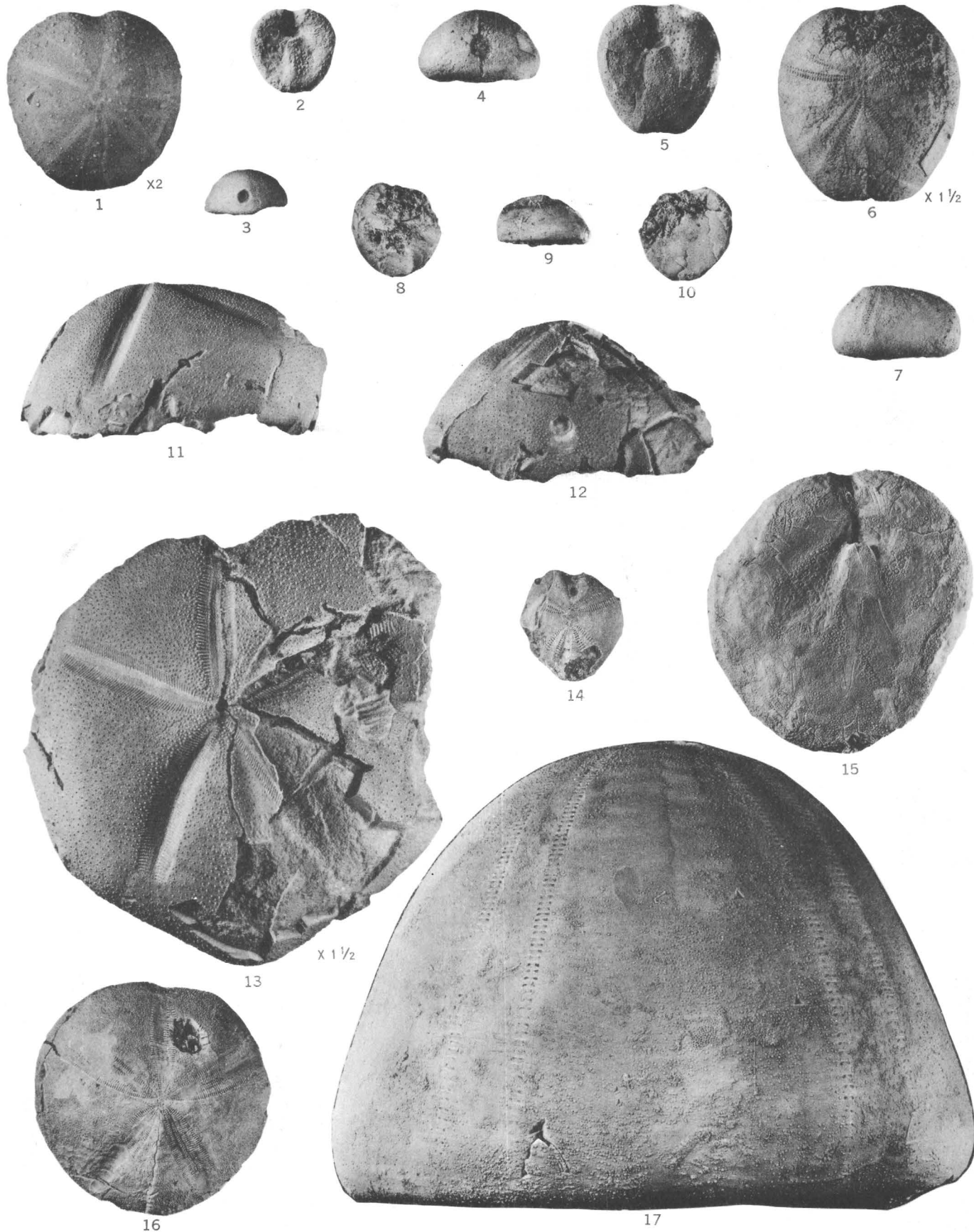
Top of cotype, U.S.N.M. 31201. From the upper part of the Pierre shale 25 miles southwest of Wibaux, Mont.

15, 16. *Isomicraster rossi* Cooke, n. sp. (p. 29).

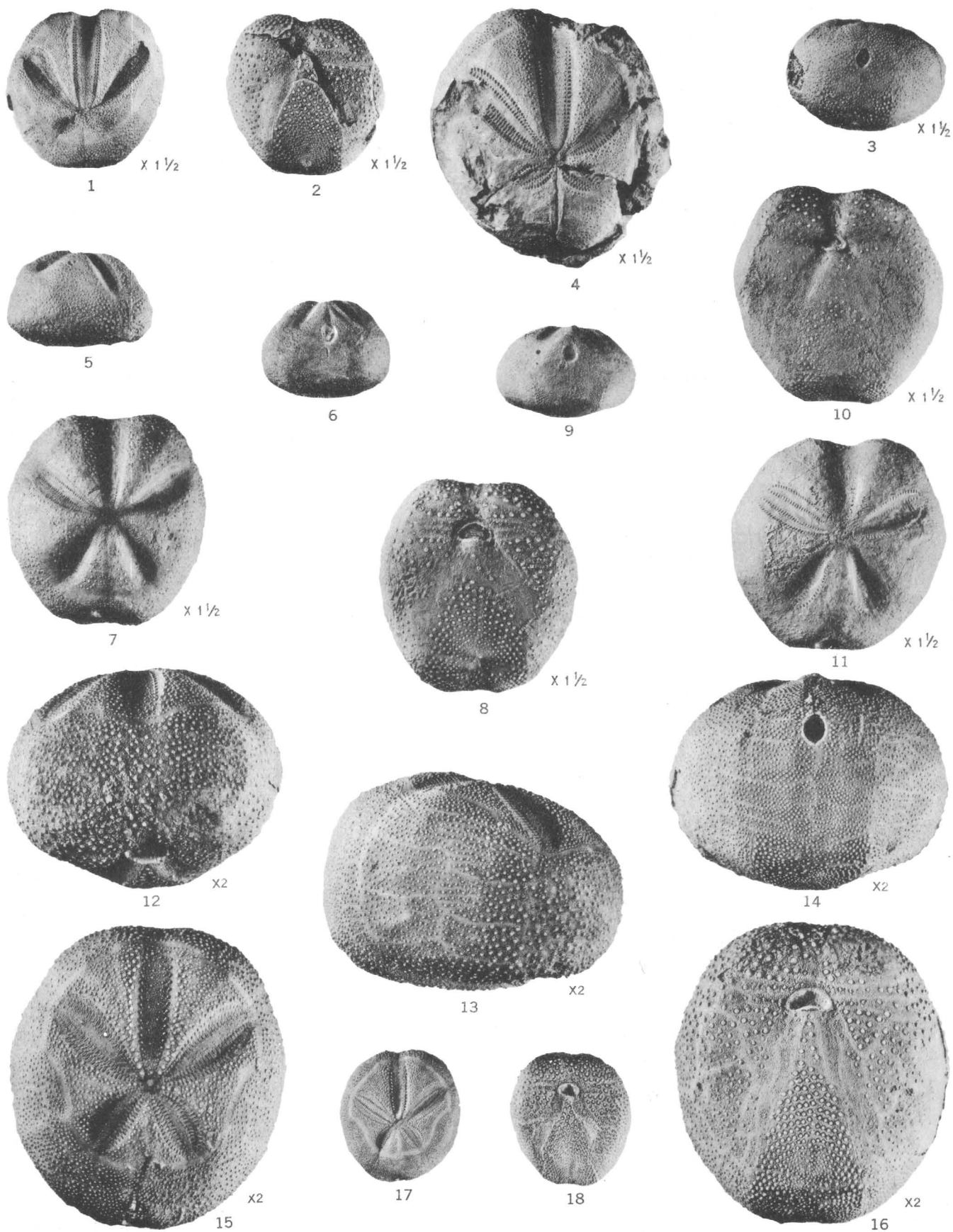
Bottom and top of two cotypes, U.S.N.M. 108392. From the Eagle Ford shale at U.S.G.S. 16855, Terlingua region, Texas.

17. *Echinocorys texanus* (Cragin) (p. 25).

Left side of U.S.N.M. 108388. From the Anacacho limestone at U.S.G.S. 12909, Seco Creek 3 miles north by west of D'Hanis, Tex.



CARDIASTER, ISOMICRASTER, AND ECHINOCORYS



HEMIASTER

PLATE 12

[All figures natural size except as indicated on plate]

- FIGURES 1-4. *Hemiaster humphreysanus* Meek and Hayden (p. 30).
1-3, Top, bottom, and posterior end of U.S.N.M. 108393, from the Nacatoch sand at U.S.G.S. 13541, Ouachita River $1\frac{1}{2}$ miles above Arkadelphia, Ark.
4, U.S.N.M. 108394, from the Mobridge member of the Pierre shale at U.S.G.S. 6641, Terry Field, Wyo.
- 5-11. *Hemiaster jacksoni* Maury (p. 33).
5-8, Right side, posterior end, top, and bottom of U.S.N.M. 108395, from the Turonian at U.S.G.S. 16952, Bom Jesus, Sergipe, Brazil.
9-11, Posterior end, bottom, and top of U.S.N.M. 108396, from the Eagle Ford shale at U.S.G.S. 14174, 21 miles west of Langtry, Tex.
- 12-16. *Hemiaster arcolensis* Cooke, n. sp. (p. 32).
Anterior end, right side, posterior end, top, and bottom of holotype, U.S.N.M. 108397. From the Arcola limestone member of the Mooreville chalk 3 miles northeast of Haynesville, Lowndes County, Ala.
- 17, 18. *Hemiaster wetherbyi* De Loriol (p. 31).
Top and bottom of U.S.N.M. 108398. From the Prairie Bluff chalk at U.S.G.S. 6856, 2 miles east of Pontotoc, Miss.

PLATE 13

[All figures natural size except as indicated on plate]

FIGURES 1-4. *Hemiaster texanus* Roemer (p. 33).

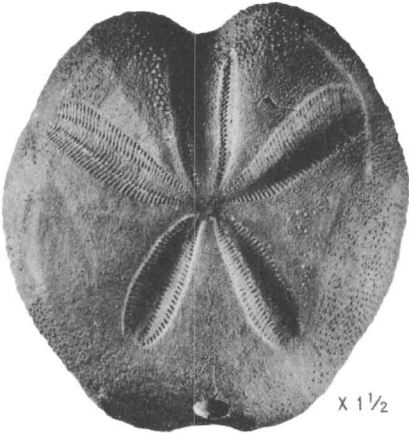
Top, bottom, right side, and posterior end of U.S.N.M. 108399. From the Anacacho limestone at U.S.G.S. 1878, Sabinal River 3 miles above Sabinal, Tex.

5, 6. "*Hemiaster*" *kümmeli* Clark (p. 35).

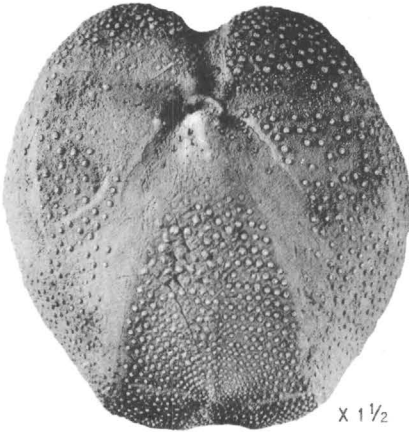
Top and bottom of holotype, New Jersey State Museum. From the Woodbury clay at Lorillard clay pits near Keyport, N. J.

7-10. *Hemiaster sabinal* Cooke, n. sp. (p. 34).

Posterior end, right side, and bottom of holotype, U.S.N.M. 108400. From the Austin chalk at U.S.G.S. 1873, Sabinal River at Dillard's ranch house.



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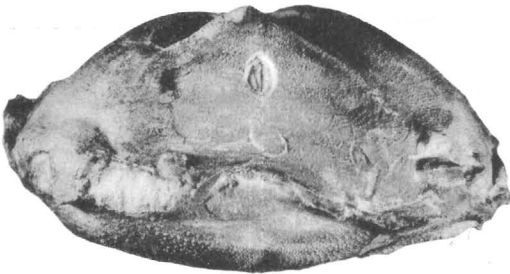
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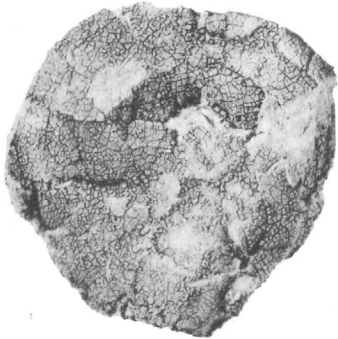
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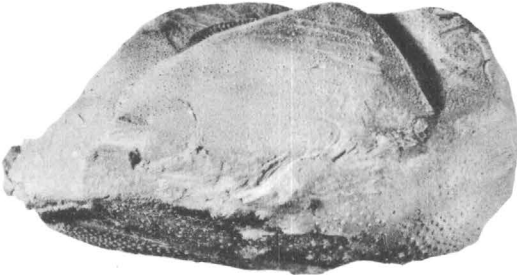
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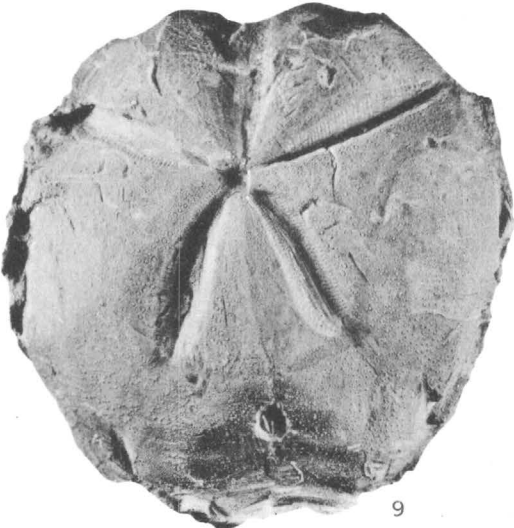
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HEMIASTER



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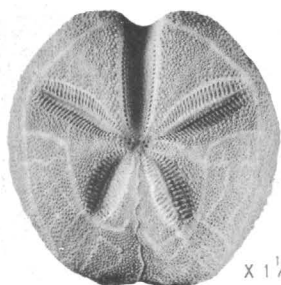
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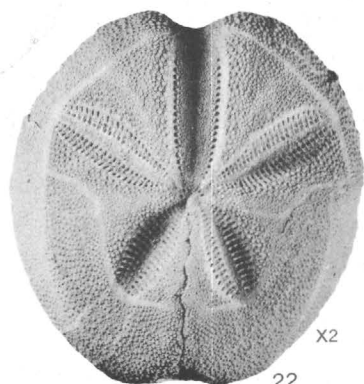


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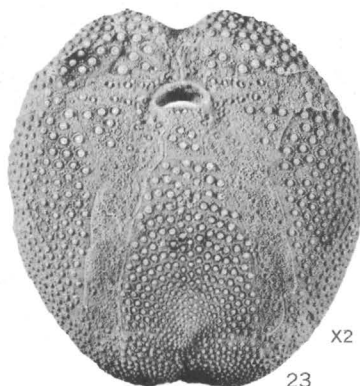
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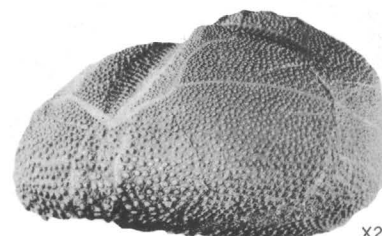
22

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CARDIASTER, HEMIASTER, AND LINTHIA

PLATE 14

[All figures natural size except as indicated on plate]

FIGURES 1-5. *Cardiaster marylandicus* Clark (p. 28).

1, 2, Bottom and top of type, Maryland Geological Survey.

3, 5, Top, bottom, and side of another specimen.

From the Monmouth formation at Brightseat, Prince Georges County, Md. All figures after Clark, 1916.

6-9. *Hemiaster delawarensis* Clark (p. 35).

Top, posterior end, right side, and bottom of holotype, Johns Hopkins University. Probably from the Mount Laurel sand 1 mile east of St. Georges, Del. After Clark, 1916.

10-14. *Hemiaster ungula* Morton (p. 34).

Top, sides, posterior end, and bottom of holotype, Acad. Nat. Sci. Philadelphia 1503. From the Delaware and Chesapeake Canal, Del.

15-17. *Hemiaster welleri* Clark (p. 35).

Top, side, and bottom of holotype, New Jersey State Museum. From the Merchantville clay in a railroad cut 1 mile south of Lower Jamesburg, N. J.

18-25. *Linthia variabilis* Slocum. (p. 36).

18-21, Bottom, top, posterior end, and left side of U.S.N.M. 73448, from U.S.G.S. 6852.

22-25, Top, bottom, posterior end, and left side of U.S.N.M. 108401, from U.S.G.S. 11652.

Both from the Brairie Bluff chalk at One Mile Run, Pontotoc, Miss.

PLATE 15

[All figures natural size except as indicated on plate]

FIGURES 1-5. *Proraster dalli* (Clark) (p. 36).

1, Top of U.S.N.M. 108402, from U.S.G.S. 12904, Rio Medina at Siphon No. 2, 4 miles north-northwest of Rio Medina, Tex.

2-5, Top, bottom, posterior end, and left side of U.S.S.M. 108403, from U.S.G.S. 17990, Grosenbacher Road, Bexar County, Tex.

Both from the Anacacho limsetone.

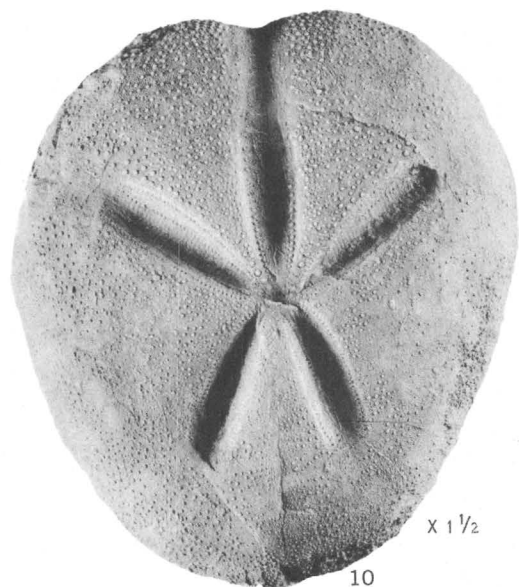
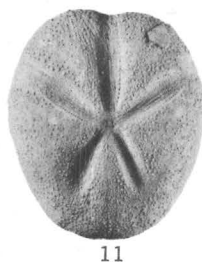
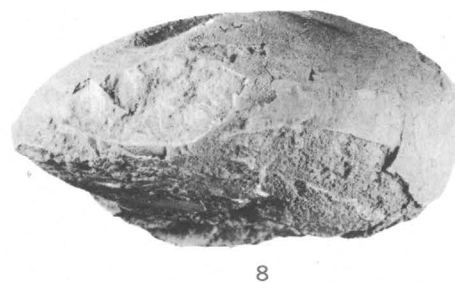
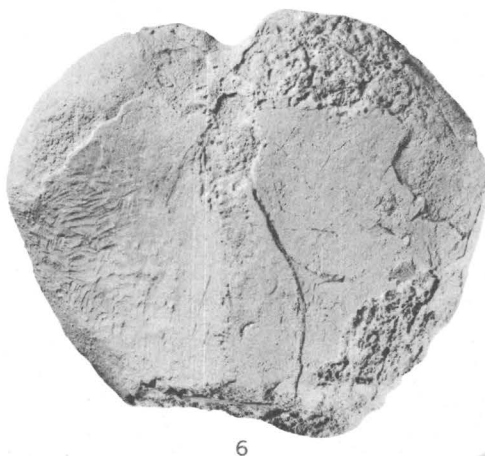
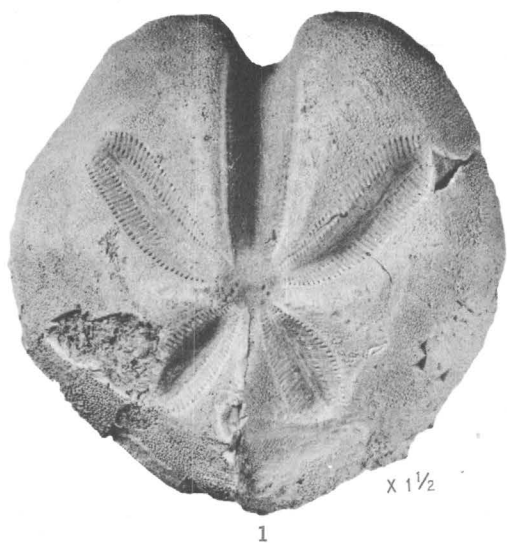
6-9. *Micraster uddeni* Cooke, n. sp. (p. 37).

Bottom of cotype 1, both sides and top of cotype 2. From the Austin chalk at U.S.G.S. 16768, Tequesquite Creek, Maverick County, Tex. U.S.N.M. 108404.

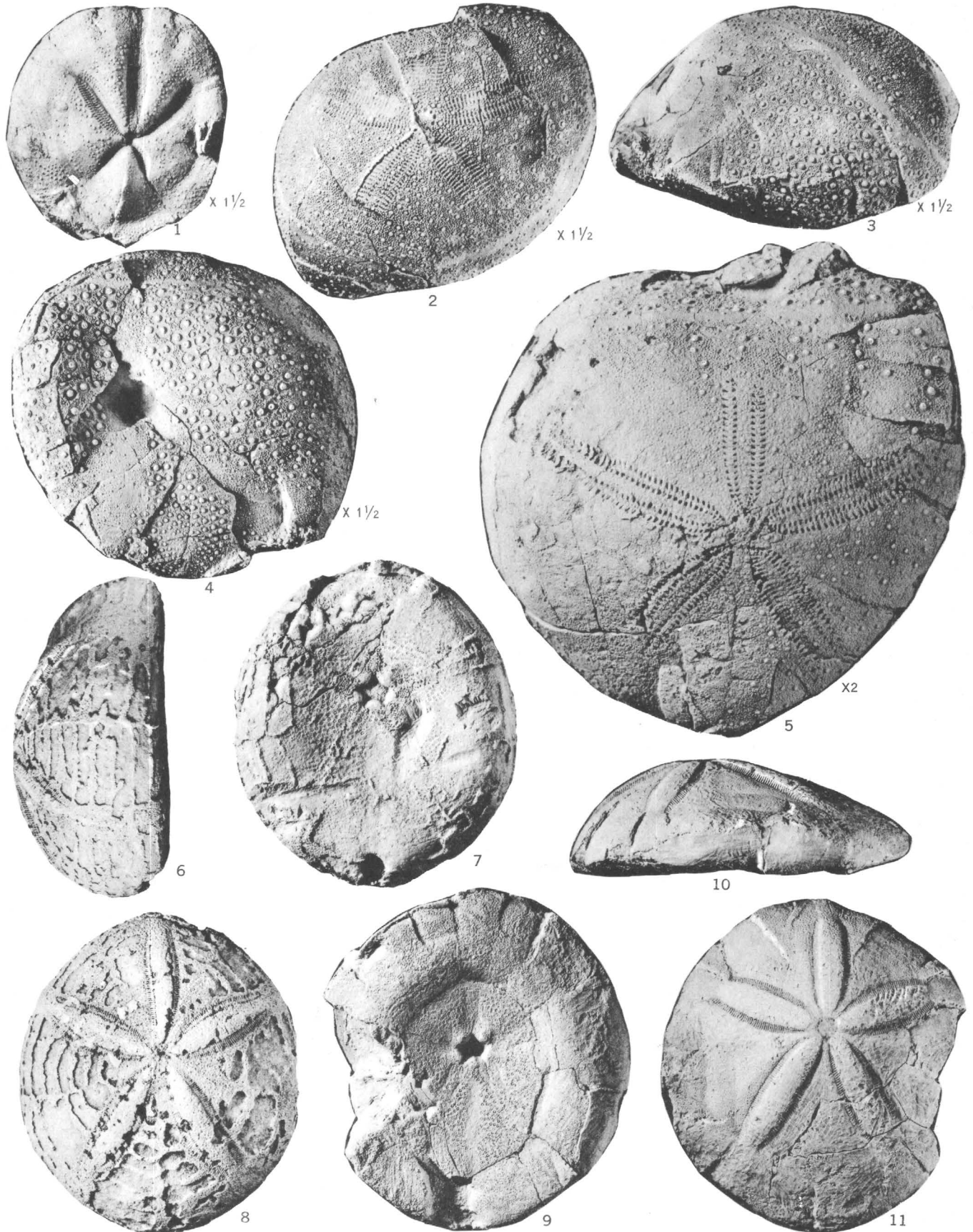
10-13. *Micraster americanus* Stephenson. (p. 38).

10, Top of U.S.N.M. 108405, from the Saratoga chalk at U.S.G.S. 13404, Saratoga, Ark.

11-13, Top, posterior end, and bottom of holotype, U.S.N.M. 76285, from the Corsicana marl at U.S.G.S. 15502, 6 miles east of Castroville, Tex.



PRORASTER AND MICRASTER



HEMIASTER, BARNUMIA, AND PYGUROSTOMA

PLATE 16

[All figures natural size except as indicated on plate]

FIGURE 1. *Hemiaster amelianus* Cooke, n. sp. (p. 35).

Type, U.S.N.M. 108408. From the Campanian (?) at Santa Amelia, Peten District, Guatemala.

2-5: *Barnumia browni* Cooke, n. sp. (p. 30).

2-4, Top, inclined side view, and bottom of cotype 1.

5, Top of cotype 2.

U.S.N.M. 108408. From the Campanian (?) at Santa Amelia, Guatemala.

6-11. *Pygurostoma pasionense* Cooke (p. 14).

6-8, Side, bottom, and top of holotype, Am. Mus. Nat. History 26901.

9-11, Bottom, side, and top of topotype, U.S.N.M. 108406. From the Campanian (?) at Santa Amelia, Guatemala.

