SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 95, NUMBER 6

NEW SPECIES OF AMERICAN EDRIOASTEROIDEA

(With Seven Plates)

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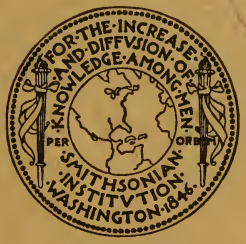

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NEW SPECIES OF AMERICAN EDRIOASTEROIDEA

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(With Seven Plates)

In a recent paper entitled "The Classification of the Edrioasteroidea,"[1] the writer presented a revised classification of this division of primitive Paleozoic echinoderms belonging to or closely related to the cystids. Six new genera were defined, two of which were based on new species, and it was stated that descriptions of additional new species upon which the classification was in part based were in contemplation. The present paper includes these descriptions, as well as comments on and illustrations of previously described species. Its main purpose is taxonomic, and these two articles present to the student a brief résumé of all genera and most of the species of the class. There is still need for further studies on the anatomical details of the edrioasteroids, but well preserved specimens are so rare that further progress along this line must necessarily be slow.

It will be remembered that these primitive echinoderms, ranging from parasitic, circular expansions to elevated, sacklike bodies, free or attached by a part or all of the lower (aboral) surface, bear normally five straight or curved ambulacra (rays or arms) on their upper (oral) surface, arranged as follows: (1) left posterior (next to anal area); (2) left; (3) anterior (opposite anal area); (4) right; (5) right posterior. Usually, four of the ambulacra curve to the left (sinistral or counterclockwise), and the fifth (the right posterior) to the right (dextral or clockwise), the anal interradius thus occurring between the right and left posteriors. However, in some genera the rays are straight, or, again, they may all curve to the left or all to the right, or, as in the first established genus, *Agelacrinites,* three to the left and two to the right. Study of many specimens has shown that the direction and extent of curvature of the ambulacra, as well as the plate structure of the rays, the interradii or interambulacral areas, and the oral area, remain constant for the genus, but the number of ambulacra, although typically five, may vary in the same species just as in the modern starfishes.

[1] Smithsonian Misc. Coll., vol. 93, no. 8, pp. 1-11, 1 pl., 1935.

In the list at the end of this paper only the articles dealing with the Edrioasteroidea in a more extensive way than the description of a species or two are cited. The bibliography of the American Ordovician and Silurian species can be found in the author's Bibliographic Index of 1915. For facility of reference the original generic name of the described species is inserted in parentheses. All the known species of the entire group are mentioned in this or the 1935 paper.

Class EDRIOASTEROIDEA Billings, 1854-58

Family STROMATOCYSTITIDAE, new family

Stromatocystites Pompeckj with its basal layer of plates and its allies *Walcottidiscus* Bassler and *Xenocystites,* new genus, are so different from the edrioasteroids with basal areas of attachment without plates that this new family seems necessary.

WALCOTTIDISCUS Bassler, 1935

Theca depressed, hemispherical to pentagonal globular, with five straight or curved ambulacra separated by polygonal interambulacral plates on the oral surface, and aboral surface completely covered by more or less polygonal plates.

Associated with the genotype, *W. typicalis* Bassler, is a second species possessing the same generic features, notably a theca as in *Stromatocystites,* but with curved ambulacra, four (1 to 4) directed to the left, and one, the right posterior (5), to the right. Better preserved specimens of this genus are necessary before the exact nature of the base can be determined, although the plate structure here appears to be as in *Stromatocystites.*

WALCOTTIDISCUS MAGISTER, n. sp.

Plate 2, fig. 2

The type specimen, a subpentagonal, depressed, semiglobular theca, 6 cm in diameter, apparently free, is, although crushed in hard shale and imperfectly preserved, sufficient to show that this is a magnificent species characterized by long, narrow, strongly curved ambulacra, four curved to the left and the right posterior to the right. The interambulacral areas are wide and occupied by large, polygonal, slightly imbricating plates, but the anal pyramid cannot be distinguished unless represented by a cluster of several small plates. The edge of the theca seems to be formed by small imbricating plates and

the under surface possibly by larger polygonal ones similar to the interambulacrals.

Good examples of this interesting species would undoubtedly reveal a beautiful and remarkable structure for this early edrioasteroid. The large proportions, strongly curved ambulacra, and numerous large polygonal interambulacral plates readily distinguish it from the associated genotype.

Occurrence.—Middle Cambrian (Burgess shale), Burgess Pass, above Field, British Columbia (loc. 35k).

Holotype.—U.S.N.M. no. 90755.

STROMATOCYSTITES Pompeckj, 1896

In this genus the under surface of the theca is completely occupied by more or less regular polygonal plates, a feature so different from most other edrioasteroids that further studies of well-preserved material are much needed. Figures of the upper and lower surfaces of the genotype, *S. pentangularis* Pompeckj, from the Middle Cambrian of Bohemia, are reproduced on plate 1, figures 6, 7.

XENOCYSTITES, n. gen.

Theca a circular, depressed, hemispherical sack with the oral surface (although not directly observed) bearing five narrow, slightly curving ambulacra undoubtedly separated by many polygonal mosaic interambulacral plates (possibly eight rows at the periphery), and the basal side made up of similar, polygonal plates either completely covering this area or possibly leaving a small central opening marking the point of attachment. Anal area not observed. Basal covering plates of ambulacra long, narrow, in a single row.

Genotype and only known species.—X. carteri, new species. Chemung of New York.

XENOCYSTITES CARTERI, n. sp.

Plate 7, fig. 14

This interesting species is based upon a flattened circular disk, 45 mm in diameter, exposing the basal side of half of the theca which is covered with polygonal plates but shows the ambulacra clearly impressed upon these basal plates. Weathering exposing the under side of the plates of the oral surface indicates that they too are polygonal and mosaic and that the ambulacra have long, narrow basal floor plates in a single row. The central part of the base consists of a

mass of jumbled plates probably representing the under side of the oral area or possibly an opening in the basal layer. The direction of ambulacral curvature is uncertain, but two of the rays seem to curve slightly to the right.

The type and only known specimen collected by A. L. Carter, of Kenmore, New York, and kindly loaned for description by the New York State Museum, is so different from other edrioasteroids that this new genus is here defined, although the surface characters cannot actually be seen.

Occurrence.—Chemung (Gowanda), Cattaraugus Creek, Versailles, New York, ½ mile up creek from bridge.

Holotype.—Collection New York State Museum.

Family HEMICYSTITIDAE, new family

Theca composed of thin plates with an oral surface of five ambulacra separated by interambulacrals and attached by the greater part of the aboral surface permanently or temporarily to some outside object. Oral covering plates three, one large plate next to the anal area with two smaller adjacent ones.

Hemicystites Hall, 1852, *Cystaster* Hall, 1871, *Cincinnatidiscus* Bassler, 1935, *Carneyella* Foerste, 1916, *Streptaster* Hall, 1872, *Lebetodiscus* Bather, 1908, *Foerstediscus* Bassler, 1935, and probably *Pyrgocystis* Bather, 1915, all agree in the very definite number and arrangement of the oral plates as well as the other characters mentioned above, so that this feature is believed to be of family importance.

CYSTASTER Hall, 1871

The view of the genotype *C.* (*Hemicystites*) *granulatus* (Hall) on plate 1, figure 14, clearly exhibits the generic characters, namely, a theca in the form of an attached elevated elongate sack with five short straight ambulacra, minute, fused, rounded or polygonal interambulacral plates in mosaic, small scalelike marginal plates, and a raised anal pyramid of very small nodose plates.

CYSTASTER ULRICHI, n. sp.

Plate 2, figs. 3-5

This species, named in honor of Dr. E. O. Ulrich, is based upon a single example about 4 mm in diameter attached to a ramose bryozoan. It differs from the genotype and only other known species in the shorter, broader sack forming the basal portion of the theca, and in

the coarser and fewer plates covering the ambulacral areas, there being two rows of 5 or 6 plates to each ambulacrum, in contrast to 9 or 10 in Hall's species. All plates show a punctate structure. The oral plates, one large and two small ones opposite it, are quite visible. Interambulacral plates minute, nodose; anal pyramid indistinct but visible.

Occurrence.—Cincinnatian (Eden shale-Economy beds), West Covington, Kentucky.

Holotype.—U.S.N.M. no. 42138.

CINCINNATIDISCUS Bassler, 1935

Species of this genus, formerly confused with *Hemicystites,* show most resemblance to *Cystaster* except that the theca is depressed or flat, attached by the whole basal surface, and the interambulacral plates are squamose, imbricating distinctly, and surrounded by a marginal zone of small nodose plates.

CINCINNATIDISCUS (HEMICYSTITES) STELLATUS (Hall), 1856

Plate 2, figs. 11, 12

This edrioasteroid, the type of the genus, is not so uncommon and thus affords opportunity for the study of specific variations. Figure 11 on plate 2 shows that the number of rays may vary as in other genera. The theca, averaging 8 mm in diameter, is attached, depressed, pentagonal, with usually five straight, short, broad, club-shaped rays bearing usually 12 covering plates to a row, each plate being almost as wide as long. Supraoral plates three, a large one opposite the anal area, and opposite this two smaller ones. Anal pyramid of very small nodose plates. Interambulacral plates imbricating, squamose, the central ones larger, and the outer marginal ones smaller and covered with small nodes.

Occurrence.—Cincinnatian (Maysville-Fairmount and Bellevue formations), Cincinnati, Ohio, and vicinity.

Plesiotypes.—U.S.N.M. no. 42106.

CINCINNATIDISCUS (HEMICYSTITES) CARNENSIS (Foerste), 1914

Plate 5, fig. 4

Theca discoidal, faintly pentagonal, 7 mm in diameter, with prominent rays, subclavate in outline, similar to *C. stellatus* (Hall) but differing in its narrower rays and correspondingly wider interambulacral areas.

Occurrence.—Trenton (*Strophomena vicina* zone), Carntown, Kentucky.

Cotype.—U.S.N.M. no. 87163.

CINCINNATIDISCUS TURGIDUS, n. sp.

Plate 5, fig. 12

Based upon a single specimen, 8 mm in diameter, associated with *Isorophus austini* (Foerste) encrusting a *Rafinesquina* shell. Except that the fifth ray has been destroyed, the theca is well preserved and shows the usual generic characters. The ambulacral covering plates, 10 to 12 to each row, are about as broad as in *C. stellatus* (Hall), but are much longer in the middle part of the ray, becoming considerably narrowed at the extremity, thus giving the ambulacra a swollen aspect. Although this is emphasized in the type specimen by the fact that the plates of several rays have been pulled apart slightly, nevertheless they are clearly wider in the midlength of a normal ray.

Occurrence.—Richmond (Whitewater formation), Oxford, Ohio.

Holotype.—U.S.N.M. no. 87628.

CINCINNATIDISCUS EDENENSIS, n. sp.

Plate 2, fig. 10; plate 3, fig. 11

Similar to *C. stellatus* (Hall) in general features, but differing in that the rays are broader and the ambulacral covering plates are much longer and so narrow, erect, and imbricating that they appear as sharp edges.

Occurrence.—Cincinnatian (Eden-McMicken beds), Cincinnati, Ohio.

Holotype.—U.S.N.M. no. 34413.

CARNEYELLA Foerste, 1916

Theca typically elevated, sacklike, attached by a broad basal part, but also of depressed parasitic disks; ambulacra curved, four to the left and the right posterior to the right. Oral area of three plates, one large, next to the anal region, and opposite these two small. Surface of plates minutely pitted but often ornamented with conspicuous nodes and ridges.

Three well-marked new forms here noted with four previously known, ranging from the base of the Trenton through the Richmond, give this genus a good representation and range. *C.* (*Agelacrinus*)

pileus (Hall), the genotype, forms hemispherical sacks about 15 mm wide and 5 mm high, attached by a broad base, in which the surface ornamentation other than the minute punctations is wanting save on the marginal plates. *Carneyella* (*Lebetodiscus*) *platys* (Raymond), 1915 (pl. 7, fig. 15), from the Trenton of Canada, and *C. raymondi* Clark, 1919, from the Trenton of New York, are referred to the genus with doubt.

CARNEYELLA (AGELACRINUS) VETUSTA (Foerste), 1914

Plate 2, fig. 14

This species is refigured to show that the papillose surface ornament of the plates is a part of the theca and not an incrusting hydroid like *Dermatostroma,* as once believed. Such surface ornamentation, although very well developed here, occurs in various degrees in all species of the genus and, indeed, forms one of the generic characters. The very short, much curved ambulacra and the broad band of highly nodose marginal plates in connection with the depressed disk form of the theca, and the many papillae hiding the outlines of the plates, are the specific characters.

Occurrence.—Trenton (Cynthiana formation), Clay's Ferry, 14 miles southeast of Lexington, Kentucky.

Holotype.—U.S.N.M. no. 87162.

CARNEYELLA NICKLESI, n. sp.

Plate 2, fig. 13

This well-characterized new species, named in honor of John M. Nickles, bibliographer of American geology, is distinguished at once from all others of the genus by its long, broad, much curved ambulacra, with about 20 short, wide covering plates in each row, and by the large, slightly imbricating, plainly visible interambulacral plates not obscured by surface ornamentation, which in this case consist of minute papillae arising from the finely punctate surface.

C. cincinnatiensis Bassler (pl. 2, fig. 15) has a similarly depressed theca and surface ornamentation, but here there are fewer covering plates to a row, the ambulacra curve less strongly, and the whole appearance is less robust.

Occurrence.—Trenton (Curdsville limestone), near Troy, Woodford County, Kentucky.

Holotype.—U.S.N.M. no. S-3191.

CARNEYELLA ULRICHI, n. sp. (Bassler and Shideler)

Plate 6, figs. 5, 6

Theca an elevated sack about 20 mm wide and 10 mm high, with the general features of *C. pileus*, but differing decidedly in the very spinous surface ornamentation of the plates. In both species the plates are minutely punctate, but in *C. ulrichi* each plate bears at least one round, swollen pustule ending in a sharp, pointed spine, and the larger plates have a number of such elevations all sharply marked and distinct from each other. Each of the ambulacral plates bears a sharp, rounded spine on the outer half and a similar elevation emerges from the inner edge. The interambulacrals have one to four such spines, and each of the larger elongate marginal plates sometimes bears several dozen. Each of the outermost series of small plates has a single spine in the center.

This and the following new species, as well as several other species herein described, were discovered by Dr. W. H. Shideler and generously presented to the National Museum. The writer has included Dr. Shideler as coauthor of these two species, since both of us wish to name them in honor, respectively, of Drs. Ulrich and Foerste, whose knowledge of the edrioasteroids as well as of other groups has always been at our service.

Occurrence.—Cincinnatian (Maysville-Bellevue formation), railroad cut, south of Maysville, Kentucky.

Holotype.—U.S.N.M. no. S-3964.

CARNEYELLA FOERSTEI, n. sp. (Bassler and Shideler)

Plate 6, figs. 7, 8

This well marked species of the *C. pileus* group is similar to the preceding in its general characters but differs in its more robust theca and broader, longer, more developed ambulacra, and particularly in the surface ornament. Each of the ambulacral plates has one to four round pustules on the broad end next to the interambulacral area and a single ridgelike elevation longitudinally arranged along the rest of the plate. Elsewhere one to a dozen round pustules rise from each of the finely punctate plates, whereas in *C. ulrichi* the corresponding elevations are sharp-pointed spines.

Occurrence.—Richmond (Arnheim formation), Russellville, Ohio.

Holotype.—U.S.N.M. no. S-3965.

CARNEYELLA (AGELACRINUS) FABERI (Miller), 1894

Dr. Foerste has refigured the type of this species, stating that it is too poorly preserved to merit description but that the occurrence of numerous tubercles on the plates suggests relationship to *Carneyella.* It is, therefore, probable that the species can be held as valid when similarly ornamented and more complete specimens from this horizon are found.

Occurrence.—Richmond (Whitewater formation), between Osgood and Versailles, Indiana.

STREPTASTER Hall, 1872

This genus is well characterized by the sinistral curvature of all its rays and by the small polygonal interambulacral plates forming a mosaic. The number of ambulacra, although normally five, varies. *S.* (*Agelacrinus*) *septembrachiata* (Miller and Dyer) more often has five rays instead of seven as in the type. Specimens of *S. reversata* Foerste, more complete than the original, which has one ray reversed, will probably show it to be better placed in *Carneyella.*

LEBETODISCUS Bather, 1908

As shown by the genotype, *L.* (*Agelacrinites*) *dicksoni* (Billings), 1857 (pl. 1, fig. 11), all five ambulacra are directed toward the left, resembling *Streptaster* in this respect, but the latter has strongly curving arms closely arranged and lacks the large mosaic interambulacral plates.

LEBETODISCUS LORIFORMIS Raymond, 1915

Plate 3, fig. 10

A view of the type specimen of this species is here introduced to show the relationship of the genus to *Carneyella,* differing in that all of the ambulacra curve strongly to the left and that large mosaic interambulacral plates separate the rays.

Occurrence.—Middle Trenton (Cystid beds), Ottawa, Ontario.

Plastotype.—U.S.N.M. no. S-3882. Original in Victoria Memorial Museum, Ottawa.

FOERSTEDISCUS Bassler, 1935

Three well marked species, the genotype *F. grandis* Bassler, 1935, from the Trenton of Kentucky, and the two herein described, agree exactly in the dextral curvature of all the arms and the mosaic

arrangement of the interambulacrals, the essential generic characters. *Cooperidiscus* has a similar arrangement of ambulacra, but the interambulacrals are highly imbricated.

FOERSTEDISCUS SPLENDENS, n. sp.

Plate 7, fig. 13

The theca, a depressed semiglobose sack about 3 cm in diameter resting upon a limestone layer, is very similar to the genotype in its general characters but differs decidedly in the greater length of its much more curved ambulacra, which in addition have more numerous plates in each row. The anal pyramid also differs in that here it is a narrow elevated tube instead of a flat broad area of small plates as in *F. grandis*.

The type specimen, a splendid example of these rare fossils, collected by Irving G. Reimann, was obtained for description through the courtesy of Dr. C. R. Stauffer, of the University of Minnesota.

Occurrence.—Black River (Decorah shale, top of *Rhinidictya* bed), Ford plant, St. Paul, Minnesota.

Holotype.—U.S.N.M. no. S-4079.

FOERSTEDISCUS PARVUS, n. sp.

Plate 2, figs. 6, 7

This species, represented by a dozen examples all exactly similar to the two cotypes figured, differs from the genotype in the small size of the theca, about 6 mm in diameter, the general delicacy of its parts, and the more imbricating nature of its interambulacral plates. The strongly curved ambulacra all directed to the right, and the anal area composed of small irregularly arranged plates, are generic features common to the two species.

Occurrence.—Trenton (Hull formation), Kirkfield, Ontario.

Cotypes.—U.S.N.M. no. S-3889.

PYRGOCYSTIS Bather, 1915

This genus, introduced here for sake of completeness, is described and its component species listed in our 1935 paper. The theca is a high cylindrical turret of overlapping plates surmounted by the oral surface with five broad straight ambulacra.

HEMICYSTITES Hall, 1852

The writer has shown that this genus, usually associated with the structure shown in *Cincinnatidiscus* (*Agelacrinus*) *stellatus* (Hall),

is in reality, according to its genotype, *H. parasiticus,* a *Carneyella* with broad, short, straight ambulacra and with squamose imbricating overlapping plates. The genus is the most prolific of all the edrioasteroids so far known. New figures of the genotype and of several previously known species referred to other genera, as well as illustrations of Barrande's species (pl. 7, figs. 2-6), are introduced here in addition to the description of several new species.

HEMICYSTITES PARASITICUS Hall, 1852

Plate 4, figs. 5, 6

The original figure is diagrammatic, as it is based upon a somewhat crushed and broken specimen, but comparison of the type with a complete example from the same horizon and locality shows the generic as well as specific features of the species. The ambulacra are short, broad, and straight, with numbers 1 and 5, between which the anal pyramid is located, diverging at a wider angle than the rest. The interambulacral plates are elongate, polygonal, imbricating, and the marginal rows of plates, six or seven in number, increase in size from a row of minute ones at the edge to a row composed of large plates encircling the ambulacra. The anal area is large, consisting of six or seven elongate triangular plates meeting in pyramid form.

Occurrence.—Clinton (Rochester shale), Lockport, New York.

Plesiotype.—U.S.N.M. no. S-3183.

HEMICYSTITES (LEBETODISCUS) MULTIBRACHIATUS (Raymond), 1915

Plate 4, figs. 3, 4

The holotype of this species (fig. 3) is surely an abnormal individual in which the original five ambulacra have been increased to eight by branching of numbers 1, 2, and 4. The same locality affords very similar specimens with the normal five ambulacra (fig. 4), for which reason such specimens are included under the same name irrespective of the number of arms in the type. *H. multibrachiatus* can be recognized by its short, widely separated straight ambulacra with seven to eight covering plates to a row, surrounded by a broad band of rather nodose, imbricating plates.

Occurrence.—Trenton (Hull formation), Kirkfield, Ontario.

Plesiotype.—U.S.N.M. no. S-3894.

HEMICYSTITES (LEBETODISCUS) CHAPMANI (Raymond), 1915

Plate 3, fig. 9

This very beautiful species is remarkable for the length of the ambulacral areas, which are broad in the oral region and taper gradu-

ally, with about 15 covering plates to a row, all arched along the median line of junction. The species is so much like *H. rectiradiatus* (Shideler) (pl. 5, fig. 10) from the Richmond group that differences are hard to note. When magnified to the same diameter and compared, *H. rectiradiatus* seems to have slightly longer, narrower, less tapering ambulacra. Related also to *H. youngi,* it differs in having longer, more slender rays.

Occurrence.—Trenton (upper part *Prasopora* zone), near Jackson Park, Peterborough, Ontario.

Plastotypes.—U.S.N.M. no. S-3892. Originals in Victoria Memorial Museum, Ottawa.

HEMICYSTITES (LEBETODISCUS) YOUNGI (Raymond), 1915

Plate 3, fig. 1

Although probably related to *H. chapmani* (pl. 3, fig. 9), the relatively shorter and broader rays will distinguish *H. youngi.* Compared with *H. billingsi,* a very similar species, *H. youngi* differs in the broader rays and in lacking the large punctate marginal plates. The short, wide ambulacra and the unusual size and length of the ambulacral covering plates, as well as the overlapping interambulacrals, readily characterize this species.

Occurrence.—Middle Trenton, Eldon Township, Victoria County, Ontario.

Plastotype.—U.S.N.M. no. S-3896. Original in Victoria Memorial Museum, Ottawa.

HEMICYSTITES (AGELACRINUS) BILLINGSI (Chapman), 1860

Plate 3, fig. 2

The photograph on plate 3 of Raymond's plesiotype of this species indicates a *Hemicystites* similar to *H.* (*Lebetodiscus*) *youngi* (pl. 3, fig. 1) but distinguished by its larger marginal and interambulacral plates, its shorter rays, and by the pitted condition of all the plates.

Occurrence.—Trenton (Cystid beds), near Jackson Park, Peterborough, Ontario.

Plastotype.—U.S.N.M. no. S-3891. Original in Victoria Memorial Museum, Ottawa.

HEMICYSTITES CURTUS, n. sp.

Plate 4, fig. 8

This minute species, which occurs as a slightly convex theca about 6 mm in diameter attached to a limestone slab, may be distinguished

at once by the large size of its three oral plates and the very short, broad, rapidly tapering ambulacra with only four or five covering plates in a row. Other features are the well-developed anal pyramid occupying a considerable portion of the interambulacral area, and the row of very large plates immediately encircling the tips of the ambulacra. The other rows of encircling plates and the interambulacral plates are small in contrast.

Occurrence.—Black River (Platteville limestone), Rockton, Illinois.

Holotype.—U.S.N.M. no. 42105.

HEMICYSTITES GERMANUS, n. sp.

Plate 4, fig. 7

Although apparently closely related to *H. curtus* in its short, broad ambulacra, the two individuals attached to a brachiopod shell on which the present species is based differ in that the covering plates are smaller and more numerous in each ambulacral row, and the encircling rows of marginal plates are less differentiated, smaller, and more imbricating.

Occurrence.—Trenton (Catheys formation), Love Branch, Maury County, Tennessee.

Cotypes.—U.S.N.M. no. 42140.

HEMICYSTITES PAULIANUS, n. sp.

Plate 4, fig. 9

In general aspect this species is very similar to *H. germanus,* from which it differs, however, in that the ambulacra are longer, taper more slowly, and contain more covering plates in each row.

Occurrence.—Black River (Decorah shale, *Phylloporina* bed), St. Paul, Minnesota.

Holotype.—U.S.N.M. no. 42114.

HEMICYSTITES RICHMONDENSIS, n. sp.

Plate 5, figs. 5-7

Theca small, averaging 7 mm in diameter, with ambulacra short, straight, wide, not narrowing much toward their extremity, bearing 6 to 8 plates in each row, and surrounded by a broad rim of punctate, wide plates, and then by several marginal rows of smaller plates.

This rather widespread Richmond species differs from the associated *Isorophus austini* in that the arms are broad and straight instead

of narrow and curved, and in the three large oral plates characteristic of the genus instead of numerous small ones. It is not the young of some other edrioasteroid because the numerous specimens discovered all maintain the same maximum size with the typical structure of the genus.

Occurrence.—Richmond, Warren County, Ohio, and Versailles, Indiana (Waynesville formation), Oxford, Ohio (Liberty), and Adams County, Ohio (Whitewater).

Cotypes.—U.S.N.M. nos. 40742, 42111, 68333.

HEMICYSTITES (AGELACRINITES) RECTIRADIATUS (Shideler), 1918

Plate 5, fig. 10

The type specimen of this magnificent species is a flattened theca about 18 mm in diameter attached to a clay pebble. It is characterized by long, narrow, straight arms tapering only at their extremity, separated by wide interambulacral areas covered by large polygonal, little imbricating plates and with an oral area of one large and two small plates, all encircled by a broad band of marginal plates, very large in the inner row and small around the edge. Comparison with the very similar *H. chapmani* is noted under that species.

Occurrence.—Richmond (Lower Whitewater), Olive Branch, Harshaville, Adams County, Ohio.

Holotype.—U.S.N.M. no. S-3954.

HEMICYSTITES DEVONICUS, n. sp.

Plate 7, fig. 1

Theca small, 6 mm in diameter, attached to a *Chonetes*. The interambulacral and oral plates are rather large and somewhat disturbed, but show distinctly that the rays are exceptionally short, straight, broad at the oral end, and taper very rapidly, with only 4 or 5 plates to a row. Other features as in the genus. The very short, rapidly tapering ambulacral rows distinguish this species from all others of the genus.

Occurrence.—Devonian (Long Lake beds), abandoned shale pit of Alpena Portland Cement Company, Alpena County, Michigan.

Holotype.—Collection Geological Department, University of Michigan, no. 17295.

HEMICYSTITES (?) CARBONARIUS, n. sp.

Plate 4, figs. 10, 11

This curious edrioasteroid occurs as thin, parasitic disks, the largest 11 mm in diameter, attached to a smooth cephalopod shell. The ambulacral areas although radiating straight from the center are obscured as to their detailed structure. This radiate arrangement and the aspect of the encircling rows of plates are so like *Hemicystites* that the species can be referred there at least provisionally. Young specimens show even less definite arrangement of the ambulacral plates than mature examples.

Occurrence.—Pennsylvanian (Bluefield shale), railroad cut $\frac{4}{5}$ mile east of Adds Valley, West Virginia.

Cotypes.—U.S.N.M. no. 91837.

Family AGELACRINITIDAE Bassler, 1935

Theca as in the Hemicystitidae except that the plates covering the oral area are small, numerous, and without any definite order. A single row of ambulacral flooring plates overlapping proximally.

Agelacrinites Vanuxem, 1842, *Isorophus* Foerste, 1916, *Isorophusella* Bassler, 1935, *Thresherodiscus* Foerste, 1914, *Discocystis* Gregory, 1897, *Cooperidiscus* Bassler, 1935, *Ulrichidiscus* Bassler, 1935, and *Lepidodiscus* Meek and Worthen, 1868, are placed in this family as restricted, the arrangement of the oral covering and ambulacral flooring plates being regarded as important characters.

THRESHERODISCUS Foerste, 1914

In this genus the branching of the ambulacral rays is carried to an extreme as shown in the illustration of the oral side of *T. ramosus* Foerste, the genotype and only species from the Lower Trenton of Manitoulin Island, Lake Huron (pl. 2, fig. 8). The illustration shows also that the rays have a pronounced trimerous origin which is perhaps the condition existing in many of the edrioasteroids. The interambulacral plates are large and squamose, imbricating in the central part and smaller along the border.

AGELACRINITES Vanuxem, 1842

This genus, fairly well represented in the Upper Paleozoic of both America and Europe, is readily recognized by its five long, narrow, much curved ambulacra, two of which (4 and 5) bend to the right, and three (1, 2, 3) to the left, and by the sculptured, mosaic inter-

ambulacral plates. The genotype, *A. hamiltonensis* Vanuxem (pl. 1, fig. 18), originally figured in a reversed position, is a handsome fossil of the Hamilton group of New York. *A. rhenanus* Roemer, 1851, from the Devonian of Germany, selected as genotype of *Haplocystites* by Roemer and later changed to *Haplocystis* by Bather (pl. 1, figs. 12, 13), proves to be founded upon a mould of the underside of part of the oral disk of a typical *Agelacrinites*. *A. blairi* Miller, 1894, from the Warsaw limestone at Boonville, Missouri, was incorrectly figured since the type specimen shows that the rays curve as in typical *Agelacrinites* (pl. 7, fig. 9). *A. legrandensis* Miller and Gurley, 1894, was based upon a mutilated specimen showing only four ambulacra, but our illustration (pl. 4, fig. 13) of an excellent example in the Springer collection from the same horizon and locality, shows a normal number and arrangement of the ambulacra.

AGELACRINITES SOUTHWORTHI, n. sp.

Plate 4, fig. 12

This handsome species is based upon a specimen perfect in all details except that the left posterior ray and the adjoining interambulacral plates are slightly crushed and in part destroyed. As our photograph shows, the structure of the rays is similar to that in the genotype, but their length falls far short since they end a little distance beyond their angle of curvature. The interambulacral plates, which are large, smooth, and imbricating, differ markedly from the sculptured polygonal, very slightly overlapping plates of the genotype. A closer relative is perhaps *A. hanoveri* Thomas (pl. 7, fig. 10) from the Shell Rock division of the Devonian at Mason City, Iowa, in which the ambulacra are very similar, but a ridge composed of the inner rows of encircling plates is present, and the arms are still shorter.

The specific name is in honor of Charles Southworth, of Thedford, Ontario, whose researches in the Hamilton rocks of Ontario have brought to light many fine fossils.

Occurrence.—Hamilton (Arkona beds, 20 to 30 feet below the Encrinal limestone), Marsh's Mill, Arkona, Ontario.

Holotype.—U.S.N.M. no. S-3478.

ISOROPHUS Foerste, 1916

In this genus the oral area is covered by numerous small plates and an extra series of ambulacral covering plates often occurs between the usual two rows. The interambulacral plates, scalelike and more or

less imbricating, and the circular depressed attached theca with ambulacral rays 1 to 4 curving to the left and 5 to the right, are other features of the genus. *I.* (*Agelacrinus*) *cincinnatiensis* (Roemer) (pl. 5, fig. 11), the genotype, and one of the less rare of the edrioasteroids, was originally figured with the rays curving in the opposite direction, but this was due to reversal of the image produced in drawing with the camera lucida of that time. Wherever noted, young specimens of *Isorophus* exhibit short, less curved rays and a broader oral area than in the mature forms.

ISOROPHUS TENNESSEENSIS, n. sp.

Plate 2, fig. 1

Theca a thin disk about 8 mm in diameter adherent to a brachiopod shell (*Rafinesquina*). The species has the ambulacral and oral plate arrangement of the genus, but with the oral area rather broad and composed of an unusually large number of small plates and the ambulacra shorter than usual although strongly curved. The small theca, rather narrow, short, much curved ambulacra, large oral area, and broad rim of marginal plates characterize this species. *I. trentonensis,* new species, from the Trenton limestone of New York, is similar but has shorter, wider little curved rays, and the oral covering plates are larger.

Occurrence.—Trenton (shaly beds in Cannon limestone), Fayetteville, Tennessee.

Holotype.—U.S.N.M. no. 91839.

ISOROPHUS TRENTONENSIS, n. sp.

Plate 5, fig. 1

As noted under *I. tennesseensis,* this new species differs in its short, broad, almost straight, bluntly terminating arms, and in the larger size of the plates forming the broad oral area. Enlarged photographs bring out these differences clearly.

Occurrence.—Trenton (upper part of Deltoidea zone), Trenton Falls, New York.

Holotype.—U.S.N.M. no. 91843.

ISOROPHUS (AGELACRINUS) AUSTINI (Foerste), 1914

Plate 2, fig. 9; plate 6, figs. 1, 2

This neat species is so small, (about 8 mm in diameter) that it might be mistaken for the young of the larger edrioasteroids, but the

photographic illustrations show it to have characteristics of typical mature *Isorophus,* differing from other species in the delicacy of its parts and its short, narrow recurved rays. One of the original types and a specimen more robust than usual, as well as an example showing the under side of the theca, are here illustrated.

Occurrence.—Richmond (Whitewater formation), Dutch Creek, 4½ miles northwest Wilmington, Ohio, Fallen Timbers Creek, Versailles, Indiana, and Dodge's Creek, Oxford, Ohio.

Cotypes and plesiotypes.—U.S.N.M. nos. 70162, S-3961, S-3963.

ISOROPHUS (AGELACRINUS) HOLBROOKI (James), 1878

Plate 5, figs. 8, 9

This, the most striking species of the genus, is characterized by its large size (diameter, 30-40 mm), semiglobose to hemispherical shape, numerous rows of little imbricating interambulacral plates, and the long, comparatively narrow, ambulacra recurving strongly along the edge of the theca.

Occurrence.—Richmond (Arnheim formation), Morrow, Ohio.

Plesiotype.—U.S.N.M. no. 40744.

ISOROPHUS GERMANUS, n. sp.

Plate 6, figs. 3, 4

Closely related to *I. holbrooki* and probably a derivative of it, agreeing in its semiglobose theca (20 mm wide) and other characters, but differing in the fewer number of plates in all the interambulacral areas and in the less definite arrangement of the anal plates.

Occurrence.—Richmond (Waynesville-Clarksville division), Morrow and Oxford, Ohio.

Cotypes.—U.S.N.M. nos. S-3959, S-3960.

ISOROPHUS KENTUCKYENSIS, n. sp.

Plate 6, fig. 10

Theca a subhemispherical disk 25 mm in diameter, with the general characters of *Isorophus* and related to *I. holbrooki* but differing in that the arms are shorter, less recurved, and the interambulacral plates are smaller, less regular, and more imbricating.

Although undoubtedly a new species, the type specimen is crushed and not well enough preserved to show the fine details of the surface.

Occurrence.—Trenton (contact between Woodburn-Greendale formations), Lair Station, Kentucky.

Holotype.—U.S.N.M. no. S-3967.

ISOROPHUS SHIDELERI, n. sp.

Plate 6, fig. 9

This well-marked species with a theca 17 mm in diameter, equal to the usual width in the genus, is readily recognized by its long, much curved, extremely narrow rays made up of unusually small plates and separated by many comparatively small interambulacral plates. The marginal rim also, although broad, is composed of many rows of small plates. Curvature of arms, structure of oral and anal areas, and accessory plates on the ambulacra as in typical *Isorophus*.

The specific name is in honor of Prof. W. H. Shideler, of Miami University, who has collected a number of the best edrioasteroids herein described.

Occurrence.—Richmond (Elkhorn formation), just west of Hamburg, Indiana.

Holotype.—U.S.N.M. no. S-3958.

ISOROPHUS (AGELACRINUS) WARRENENSIS (James), 1883

Plate 5, figs. 2, 3; plate 6, fig. 11

The type of this species was poorly selected because in it the large interambulacral plates are sufficiently displaced by pressure to hide the ambulacra. Better specimens in the original lot, of which plate 5, figure 2, represents one, show this to be a good species characterized by its small diameter (13 mm) short, broad, slightly curved ambulacra, large polygonal, slightly overlapping interambulacral plates, broad oral area of numerous large plates, and wide marginal rim of large and small plates. The dozen or more specimens in the original lot maintain these characters as do specimens from other localities at the same horizon. The jumbled condition that the plates may assume is shown in plate 6, figure 11.

Occurrence.—Richmond, Oregonia, and near Morrow, Ohio (probably basal Arnheim formation); Clarksville, Ohio (Waynesville formation).

Holotype and plesiotype.—U.S.N.M. no. S-3957.

ISOROPHUSELLA Bassler, 1935

The large specimen of the genotype, *I.* (*Lebetodiscus*) *incondita* (Raymond), figured by the writer in 1935, very distinctly showed the

generic characteristics, three rays curved to the left and two to the right. Smaller, young examples, such as the type itself, have rays less curved, and in still younger specimens the rays are almost straight. A view of the specimen on the type slab showing the anal pyramid well preserved is represented on plate 7, figure 12, where the rays, although almost straight, show a tendency to curve left and right as in the older examples. The other characters of the genus are those of typical *Isorophus*. Typical *Agelacrinites* has the same arrangement of arms as in *Isorophusella,* but its sculptured mosaic interambulacral plates will readily distinguish it.

LEPIDODISCUS Meek and Worthen, 1868

Theca with the curvature of the ambulacra as in *Discocystis,* namely, four rays to the left and one to the right, but differing in the presence of strongly imbricating interambulacral plates. Or again, the genus resembles *Cooperidiscus* except that four of its ambulacra curve to the left instead of five to the right. In addition to *L.* (*Agelacrinites*) *squamosus* (Meek and Worthen), the genotype, (pl. 1, fig. 17), *L.* (*Agelacrinites*) *beecheri* (Clarke), *L.* (*Agelacrinites*) *buttsi* (*Clarke*) (pl. 7, fig. 8), *L.* (*Agelacrinites*) *lebouri* (Sladen) (pl. 1, fig. 19), and *L. milleri* Sharman and Newton (pl. 7, fig. 7), all from the Lower Carboniferous rocks, exhibit the curvature of ambulacra and imbricating interambulacrals characteristic of the genus. The following new species from the Middle Devonian is thus the earliest known.

LEPIDODISCUS ALPENENSIS, n. sp.

Plate 3, fig. 3

The type and only specimen, a theca about 7 mm in diameter, attached to a large *Chonetes,* shows clearly four ambulacra curved to the left and the fifth, the right posterior, to the right, as well as the strongly imbricating plates of typical *Lepidodiscus.* The anal pyramid, although somewhat broken, is large and occupies a central position between the left and right posterior rays. The small size and the combination of characters diagnostic of the genus will separate this species from other Devonian edrioasteroids.

Occurrence.—Devonian (Traverse group-Presque Island division of Long Lake formation), Quarry of the Alpena Portland Cement Company, Alpena County, Michigan.

Holotype.—Collection Geological Department, University of Michigan, no. 17296.

DISCOCYSTIS Gregory, 1897

This genus, of which three well-marked species are now known, exhibits the essential characters of *Agelacrinites* except that four of the ambulacra are curved to the left and one, the right posterior, to the right, and the theca is more sacklike, with many rows of closely imbricated marginal plates. The genotype, *Echinodiscus optatus* Worthen and Miller (pl. 1, fig. 5), was based upon the basal side of a specimen of *D.* (*Agelacrinus*) *kaskaskiensis.* Besides the genotype and the following new species, the genus includes *D.* (*Echinodiscus*) *sampsoni* (Miller), 1891, from the Warsaw of Missouri.

DISCOCYSTIS LAUDONI, n. sp.

Plate 3, figs. 7, 8

This fine species, the types of which were collected and presented by Dr. L. R. Laudon, of Tulsa University, is readily distinguished by its narrow, well-developed long ambulacra curving decidedly throughout their length. In *D. sampsoni* and *D. kaskaskiensis* the ambulacra are comparatively straight for the first third of their length and then curve rather abruptly. In other features these three species show the generic characters very uniformly.

Occurrence.—Kinderhook (Gilmore City formation), Gilmore City, Iowa.

Cotypes.—U.S.N.M. no. S-3886.

DISCOCYSTIS (AGELACRINUS) KASKASKIENSIS (Hall), 1858

Plate 1, figs. 4, 5; plate 3, figs. 4-6; plate 7, fig. 11

Agelacrinus kaskaskiensis Hall, Geol. Iowa, vol. 1, pt. 2, p. 696, pl. 25, fig. 18, 1858.

Echinodiscus optatus Worthen and Miller, Geol. Surv. Illinois, vol. 7, p. 336, pl. 18, fig. 3, 1883.

The original type of this species failed to show clearly the direction of curvature of the fifth arm, so Hall's illustration is here corrected (pl. 1, fig. 4). The great width of the zone of marginal plates (pl. 1, fig. 5, pl. 7, fig. 11) restricts the attached part of the theca to a small circular central opening. Specimens with an abnormal number of arms occur here as in other edrioasteroids, as shown on plate 3, figure 5. The covering floor plates of the ambulacra are in distinct uniserial rows (pl. 3, fig. 6).

Occurrence.—Chester group, Kaskaskia, Illinois (*D. kaskaskiensis*), Polk County, Missouri (*E. optatus*), Huntsville, Alabama (Ste. Genevieve limestone), and Grayson County and Sloans Valley, Kentucky (Glen Dean).

Plesiotypes.—U.S.N.M. nos. S-3883, S-3884.

ULRICHIDISCUS Bassler, 1935

Ambulacra all curve strongly to the left with slightly imbricated interambulacrals. *Lebetodiscus* has similar curvature, but the interambulacrals are mosaic.

Genotype and only known species.—*U.* (*Agelacrinus*) *pulaskiensis* (Miller and Gurley) from the Mississippian (Chester) of Kentucky.

COOPERIDISCUS Bassler, 1935

Theca and general characters as in *Ulrichidiscus,* but all the rays curve to the right and are separated by closely imbricating interambulacrals. *Foerstediscus* has a similar curvature, but the interambulacrals are mosaic.

Genotype and only known species.—*C.* (*Lepidodiscus*) *alleganius* (Clarke) from the Devonian (Chemung) of New York.

Family EDRIOASTERIDAE Bather

This family was founded on the character of the ambulacra, which were so strongly developed that they passed on to the aboral surface. However, this seems to be a minor feature since the dividing line between the upper and lower surface may be questionable. The occurrence of the ambulacral flooring plates in two rows is a more definite character.

Illustrations of the genotype of *Edrioaster* Billings, 1858 (pl. 1, fig. 1) and of *Dinocystis* Bather, 1898 (pl. 1, figs. 2, 3), the latter probably belonging to the family are introduced here for comparative purposes.

Family CYATHOCYSTIDAE Bassler

In this family the number of rows of marginal plates has been increased to such an extent that they form a solid, fused, more or less cone-shaped mass attached at the aboral end to some foreign object, and bearing the ambulacra at the top or free end. Two genera have been distinguished, *Cyathocystis* Schmidt, 1880, with an oral surface much as in *Stromatocystites,* and *Cyathotheca* Jaekel, 1927, in which the ambulacral areas are apparently so narrow that they are

practically hidden at the surface. *Cyathotheca suecica* Jaekel, 1927 (pl. 1, fig. 10) from the Ordovician of Sweden, and *C.* (*Cyathocystis*) *corallum* (Jaekel) 1918, occurring in the Ordovician of Russia, are the known representatives of this genus, whereas in addition to the genotype, *C. plautinae* Schmidt, 1880 (pl. 1, figs. 8, 9) and *C. rhizophora* Schmidt, 1880, from the Ordovician of Estonia, *Cyathocystis* is represented by the following closely allied new American species.

CYATHOCYSTIS AMERICANUS, n. sp.

Plate 4, fig. 1, 2

This new species, although closely allied to the European forms, known to the writer only from the rather diagrammatic drawings of Dr. Schmidt, seems to differ decidedly in the fact that the ambulacra are much broader, shorter, and taper more rapidly. The type and only specimen exhibits a subpentagonal theca with the base drawn out into rootlike processes by which it was attached. The oral surface is slightly convex, but a portion is broken away so that the anal area is not visible. The discovery of this genus in America is another bit of evidence as to the European origin of this east Tennessee Chazyan fauna.

Occurrence.—Chazyan (Blount group-Ottosee formation), Knoxville, Tennessee.

Holotype.—U.S.N.M. no. 91846.

POSITION UNCERTAIN

Certain genera which have been considered edrioasteroids in the past should now be definitely eliminated. These are *Astrocystites* Whiteaves, 1897 (pl. 1, figs. 15, 16), and *Cyclocystoides* Billings and Salter, 1858, and its allies.

Although Bather recognized *Astrocystites* as an edrioasteroid, Hudson (1925) concluded that this genus was a true blastoid and was nearer *Pentremites* than either *Asteroblastus, Asterocystis,* or *Blastoidocrinus.* These four genera are represented by so few specimens that pending further discoveries, they might well be assigned to the Protoblastoidea, the first order of blastoids.

The family Cyclocystoididae, however, does not belong to this category and must be left at present as an uncertain order of Pelmatozoa.

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EXPLANATION OF PLATES

PLATE 1

(All figures after the respective authors of the species unless otherwise stated.)

PAGE

FIG. 1. *Edrioaster bigsbyi* Billings 22
Oral side of the flexible theca, natural size, with two rows of covering and flooring plates, showing ambulacra passing to aboral side (after Bather).
Trenton (Hull): Ottawa, Ontario.

FIGS. 2, 3. *Dinocystis barroisi* Bather 22
Top and basal views one-half natural size. All the ambulacra curve strongly to the left and the aboral side is composed of closely imbricating plates and has a small central orifice for attachment.
Devonian: Condroz, Belgium.

FIGS. 4, 5. *Discocystis* (*Agelacrinus*) *kaskaskiensis* (Hall) 21
(See also pl. 3, figs. 4-6, pl. 7, fig. 11.)
4. View, natural size, of ambulacral surface of a compressed specimen. The direction of one of the ambulacra is in error and has been corrected in ink.
5. Holotype of *Echinodiscus optatus* Worthen and Miller, representing part of the aboral side of *Discocystis kaskaskiensis* composed of numerous rows of fused imbricating plates and a central area of attachment.
Chester: Kaskaskia and Polk County, Illinois.

FIGS. 6, 7. *Stromatocystites pentangularis* Pompeckj 3
Drawings of oral surface showing ambulacral areas and of lower side of theca with plated structure, slightly reduced.
Middle Cambrian: Tegrovic, Bohemia.

FIGS. 8, 9. *Cyathocystis plautinae* Schmidt 23
8. Lateral view of two individuals growing upon a pebble, natural size.
9. Sketch of oral surface, × 3, showing ambulacral areas with covering plates in part removed, and the anal pyramid and fused interambulacrals. Ordovician (*Echinosphérites* limestone): Riga, Esthonia.

FIG. 10. *Cyathotheca suecica* Jaekel 23
Top view of the cone-shaped theca, showing the pentagonal oral surface and the apparently hidden ambulacra, slightly enlarged.
Ordovician of Sweden.

FIG. 11. *Lebetodiscus* (*Agelacrinites*) *dicksoni* (Billings) 9
View, natural size, illustrating curvature of all the ambulacra to left, and large mosaic interambulacral plates.
Trenton (Hull): Ottawa, Ontario.

FIGS. 12, 13. *Agelacrinites* (*Haplocystites*) *rhenanus* Roemer 16
12. Mould of the underside of upper part of theca, natural size.
13. Cast of same, enlarged, showing ambulacral flooring plates in single rows.
Devonian: Rhine area, Germany.

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FIG. 14. *Cystaster (Hemicystites) granulatus* Hall..... 4
Side view of the elevated sacklike theca, × 3, exhibiting the straight ambulacra, the fused minute rounded, mosaic interambulacral plates, the scalelike marginal ones, the anal pyramid of raised, very small nodose plates, and the basal area of attachment.
Cincinnatian (Maysville-Fairmount): Cincinnati, Ohio.

FIGS. 15, 16. *Astrocystites ottawaensis* Whiteaves..... 23
Photograph of one of the cotypes, × 1, and outline sketch enlarged, illustrating plate structure and affinities with the blastoids. (16, after Bather.)
Trenton (Hull): Ottawa, Ontario.

FIG. 17. *Lepidodiscus (Agelacrinites) squamosus* (Meek and Worthen).... 20
Sketch of type specimen, × 1, showing very squamose interambulacra and four ambulacra curving strongly to the left and the right posterior one to the right.
Mississippian (Keokuk): Crawfordsville, Indiana.

FIG. 18. *Agelacrinites hamiltonensis* Vanuxem..... 16
View of the thin parasitic theca, × 3, exhibiting sculptured mosaic interambulacral plates and curvature of ambulacra, two (4, 5) to the right, and three (1-3) to the left.
Devonian (Hamilton): West Hamilton, New York.

FIG. 19. *Lepidodiscus (Agelacrinites) lebouri* (Sladen)..... 20
The theca, natural size, showing branching of the left posterior ray.
Lower Carboniferous of Northumberland, England.

PLATE 2

FIG. 1. *Isorophus tennesseensis,* new species..... 17
The holotype, × 4, incrusting a *Rafinesquina,* illustrating the broad, oral area of many plates, short, much curved ambulacra, and large interambulacrals.
Trenton (Cannon limestone): Fayetteville, Tennessee.

FIG. 2. *Walcottidiscus magister,* new species..... 2
The type specimen, × 0.6, crushed in hard shale but still showing the strongly curved ambulacra, 1 to 4 to the left and 5 to the right, and the polygonal mosaic interambulacral plates.
Middle Cambrian (Burgess shale): Burgess Pass, above Field, British Columbia.

FIGS. 3-5. *Cystaster ulrichi,* new species..... 4
Photograph, × 4, of the holotype attached to a bryozoan, and two drawings of the same exhibiting lateral and top views.
Cincinnatian (Eden-Economy): West Covington, Kentucky.

FIGS. 6, 7. *Foerstediscus parvus,* new species..... 10
Two examples, × 4, attached to a thin-bedded limestone layer, illustrating the curvature of all the ambulacra to the right and the much imbricated interambulacrals.
Trenton (Hull): Kirkfield, Ontario.

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FIG. 8. *Thresherodiscus ramosus* Foerste 15
Oral surface, × 2, showing much branched ambulacral rays with a pronounced trimerous origin.
Trenton (Curdsville): Goat Island, northeast of Little Current, Manitoulin Island, Lake Huron.

FIG. 9. *Isorophus* (*Agelacrinus*) *austini* (Foerste) 17
(See also pl. 6, figs. 1, 2.)
One of the type specimens, × 4, attached to a stony bryozoan.
Richmond (Whitewater): Dutch Creek, Clinton Co., Ohio.

FIG. 10. *Cincinnatidiscus edenensis*, new species 6
(See also pl. 3, fig. 11.)
One of three individuals, × 4, attached to a ramose bryozoan. The long, narrow, erect covering plates of the ambulacra are distinctive.
Cincinnatian (Eden-McMicken): Cincinnati, Ohio.

FIGS. 11, 12. *Cincinnatidiscus* (*Hemicystites*) *stellatus* (Hall) 5
11. A theca with six ambulacra, × 1.3, attached to a brachiopod (*Rafinesquina*).
12. Sketch of theca showing pentagonal outline, short, broad ambulacra, and oral plates.
Cincinnatian (Maysville-Fairmount and Bellevue): Cincinnati, Ohio.

FIG. 13. *Carneyella nicklesi*, new species 7
Theca, × 4, attached to shell, exhibiting the long, strongly curved ambulacra and the coarse plates with fine surface ornament. The anterior ray has been broken away.
Trenton (Curdsville): near Troy, Woodford Co., Kentucky.

FIG. 14. *Carneyella* (*Agelacrinus*) *vetusta* (Foerste) 7
Holotype, × 4, attached to a brachiopod, showing short, well-curved ambulacra and especially the very papillose surface ornament obscuring the plate outlines.
Trenton (Cynthiana): Clay's Ferry, 14 miles southeast of Lexington, Kentucky.

FIG. 15. *Carneyella cincinnatiensis* Bassler 7
Diagrammatic sketch of theca, slightly enlarged, showing generic characters of *Carneyella*. (after Hall).
Cincinnatian (Maysville-Corryville): Cincinnati, Ohio.

PLATE 3

FIG. 1. *Hemicystites* (*Lebetodiscus*) *youngi* (Raymond) 12
Photograph, × 3, of the holotype showing the broad, short ambulacra, and rather large interambulacral plates.
Middle Trenton: Eldon township, Victoria County, Ontario.

FIG. 2. *Hemicystites* (*Agelacrinus*) *billingsi* (Chapman) 12
View of the plesiotype figures by Raymond, × 3. The very large interambulacral plates and the pitted surface are characteristic.
Trenton (Cystid beds): Peterborough, Ontario.

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FIG. 3. *Lepidodiscus alpenensis,* new species 20
The type, × 4, incrusting a large *Chonetes.* Four rays curved to the left and the right posterior to the right, with strongly imbricating ambulacrals, are characteristic.
Traverse (Presque Isle division of Long Lake formation): Quarry, Alpena Portland Cement Co., Alpena County, Michigan.

FIGS. 4-6. *Discocystis* (*Agelacrinus*) *kaskaskiensis* (Hall) 21
(See also pl. 1, figs. 4, 5; pl. 7, fig. 11.)
4. A normal compressed theca, × 1.3, illustrating arrangement of ambulacra and mosaic interambulacrals.
5. An abnormal theca, × 1.3, with only four ambulacra.
Chester (Ste. Genevieve): Huntsville, Alabama.
6. Aboral side of theca, × 1.3, showing the narrow opening of the attached portion, the fused plates of the basal surface, the mosaic arrangement of the interambulacrals, and the single row of flooring ambulacral plates.
Chester (Glen Dean): Grayson County, Kentucky.

FIGS. 7, 8. *Discocystis laudoni,* new species 21
7. A complete, although crushed theca, × 1.3, exhibiting the strongly curved ambulacra, numbers 1 and 5 encircling the anal area.
8. Another specimen, × 1.3, exhibiting the anal area and its encircling ambulacra more clearly.
Kinderhook (Gilmore City): Gilmore City, Iowa.

FIG. 9. *Hemicystites* (*Lebetodiscus*) *chapmani* (Raymond) 11, 12
The well-preserved type, × 3, exhibiting particularly the long series of ambulacral plates.
Trenton (upper part *Prasopora* zone): Near Jackson Park, Peterborough, Ontario.

FIG. 10. *Lebetodiscus loriformis* Raymond 9
Photograph of the type specimen, × 1.7, showing the strongly curved ambulacra all directed to the left and the large mosaic interambulacrals.
Middle Trenton (Cystid beds): Ottawa, Ontario.

FIG. 11. *Cincinnatidiscus edenensis,* new species 6
(See also pl. 2, fig. 10.)
The type specimen and another individual, × 1.6, incrusting a ramose bryozoan.
Cincinnatian (Eden-McMicken): Cincinnati, Ohio.

PLATE 4

FIGS. 1, 2. *Cyathocystis americanus,* new species 23
Side and top views, × 4, of the type, a solid mass of fused plates, polygonal in outline, bearing the ambulacral surface at its slightly convex upper broad end.
Chazyan (Blount-Ottosee formation): Knoxville, Tennessee.

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FIGS. 3, 4. *Hemicystites* (*Lebetodiscus*) *multibrachiatus* (Raymond)..... 11

3. The holotype, × 4, probably representing an abnormal individual, with eight ambulacra produced by branching of the original five.

4. A specimen, × 4, of apparently the same species with a normal number of ambulacra.

Trenton (Hull formation): Kirkfield, Ontario.

FIGS. 5, 6. *Hemicystites parasiticus* (Hall)..... 11

5. The holotype, × 4, clearly identical, although broken, with the following.

6. A complete specimen, × 4, consisting of a thin, flattened disk attached to a *Spirifer*, with characteristic short, broad, straight ambulacra and large anal pyramid.

Clinton (Rochester shale): Lockport, New York.

FIG. 7. *Hemicystites germanus*, new species..... 13

Two examples, × 4, of this minute species attached to a *Rafinesquina*. The quickly tapering ambulacra with small plates and the broad oral area are characteristic.

Trenton (Catheys): Love Branch, Maury County, Tennessee.

FIG. 8. *Hemicystites curtus*, new species..... 12

The type, × 4, a beautifully preserved small disk attached to a limestone slab. The ambulacra are exceptionally short and broad and the ambulacral plates larger than usual.

Black River (Platteville limestone): Rockton, Illinois.

FIG. 9. *Hemicystites paulianus*, new species..... 13

An individual, × 4, similar to *H. germanus* but possessing larger, narrower ambulacra with more plates in each row.

Black River (Decorah shale): St. Paul, Minnesota.

FIGS. 10, 11. *Hemicystites* (*?*) *carbonarius*, new species..... 15

Holotype, × 4, and associated young example, × 4, both thin disks attached to a pelecypod shell. Although they are well-preserved specimens, the exact arrangement of the ambulacra in each is indistinct.

Pennsylvanian (Bluefield shale): Railroad cut, $\frac{4}{5}$ mile east of Adds Valley, West Virginia.

FIG. 12. *Agelacrinites southworthi*, new species..... 16

The holotype, × 4, a specimen perfect in all parts except the anal region.

Hamilton (Arkona beds, 20 to 30 feet below the Encrinal limestone): Marsh's Mills, Arkona, Ontario.

FIG. 13. *Agelacrinites* (*Agelacrinus*) *legrandensis* Miller and Gurley..... 16

A complete example, × 4, from the original locality exhibiting normal number and direction of ambulacra for the genus.

Kinderhook (Legrand formation): Legrand, Iowa.

Plate 5

PAGE

Fig. 1. *Isorophus trentonensis,* new species 17
A complete example, × 4, attached to a brachiopod, exhibiting the short, broad, slightly curved arms and the many plates of large oral area.
Trenton (upper part of Deltoidea zone): Trenton Falls, New York.

Figs. 2, 3. *Isorophus* (*Agelacrinus*) *warrenensis* (James) 19
(See also pl. 6, fig. 11.)
2. A specimen, × 3, from the original lot but better preserved than the type. The broad oral area of many plates and the stout, short, curved arms and large overlapping interambulacral plates are characteristic.
Richmond (probably basal Arnheim): Oregonia, Ohio.
3. Another specimen, × 3, attached to a brachiopod, with the ambulacra more clearly defined.
Richmond (Waynesville): Clarksville, Ohio.

Fig. 4. *Cincinnatidiscus* (*Hemicystites*) *carnensis* (Foerste) 5
One of the type specimens, × 4, a slightly worn individual.
Trenton (*Strophomena vicina* zone): Carntown, Kentucky.

Figs. 5-7. *Hemicystites richmondensis,* new species 13
5. A small example, × 4, slightly abraded, attached to a brachiopod.
6. A larger, better-preserved specimen attached to a *Rafinesquina,* × 4. The short, broad arms, practically straight, characterize the species.
7. Another small example, × 4, with plate structure well preserved.
Richmond: Warren County, Ohio (5) and Versailles, Indiana (6) (Waynesville); Adams County, Ohio (7) (Whitewater).

Figs. 8, 9. *Isorophus* (*Agelacrinus*) *holbrooki* (James) 18
8. A typical example, × 1.5, of this globose species attached to a shell. The many rows of large polygonal interambulacral plates are characteristic.
9. Lateral view of same, × 3, showing the plate detail of the anal area and the adjacent ambulacra.
Richmond (Lower Arnheim): Morrow, Ohio.

Fig. 10. *Hemicystites* (*Agelacrinites*) *rectiradiatus* (Shideler) 12, 14
Photograph of the holotype, × 3, a well-preserved specimen attached to a clay nodule, showing marked resemblance to *H. chapmani* (pl. 3, fig. 9).
Richmond (Lower Whitewater): Olive Branch, Harshaville, Ohio.

Fig. 11. *Isorophus* (*Agelacrinus*) *cincinnatiensis* (Roemer) 17
Roemer's original view of the type, reversed, slightly enlarged.
Cincinnatian (Maysville-Bellevue): Cincinnati, Ohio.

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FIG. 12. *Cincinnatidiscus turgidus,* new species 6
The holotype, × 4, exhibiting the short swollen ambulacra.
Richmond (Whitewater): Oxford, Ohio.

PLATE 6

FIGS. 1, 2. *Isorophus* (*Agelacrinus*) *austini* (Foerste) 17
(See also pl. 2, fig. 9.)
1. One of a group of specimens attached to a limestone fragment, × 4. The ambulacra are partially covered by the marginal rows of plates. Richmond (basal Saluda): Fallen Timbers Creek, Versailles, Indiana.
2. Under side of oral surface, × 4, showing the ambulacral floor plates arranged in a single row.
Richmond (Upper Whitewater): Dodges Creek, Oxford, Ohio.

FIGS. 3, 4. *Isorophus germanus,* new species 18
3. The holotype, a fairly well preserved specimen, × 2, attached to a brachiopod. The fewer rows of interambulacral plates distinguish it from *I. holbrooki.*
4. Another entire example, × 2, although slightly worn.
Waynesville (Clarksville): Morrow (fig. 3) and Oxford, Ohio.

FIGS. 5, 6. *Carneyella ulrichi,* new species (Bassler and Shideler) 8
5. The type example, × 2, a somewhat crushed specimen attached to a *Hebertella.*
6. View of surface, enlarged, showing ornamentation of oral, ambulacral and interambulacral plates.
Cincinnatian (Maysville-Bellevue): Railroad cut, south of Maysville, Kentucky.

FIGS. 7, 8. *Carneyella foerstei,* new species (Bassler and Shideler) 8
7. The holotype, × 2, a slightly crushed example attached to a *Rafinesquina.*
8. Surface ornament, enlarged, exhibiting the elongate nodes of the ambulacral plates.
Richmond (Arnheim-*Glyptocrinus* zone): Russellville, Ohio.

FIG. 9. *Isorophus shideleri,* new species 19
The complete, although slightly damaged type specimen, × 3, with the characteristic very narrow, long, much recurved ambulacra.
Richmond (Elkhorn): West of Hamburg, Indiana.

FIG. 10. *Isorophus kentuckyensis,* new species 18
The type specimen, × 2, a crushed theca attached to a limestone layer.
Trenton (Woodburn-Greendale contact): Lair Station, Kentucky.

FIG. 11. *Isorophus warrenensis* (James) 19
(See also pl. 5, fig. 2, 3.)
Photograph, × 2, of a specimen probably belonging to this species, showing jumbled condition of plates.
Richmond (basal Arnheim): Mouth of Second Creek of Todds Fork, Warren County, Ohio.

Plate 7

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Fig. 1. *Hemicystites devonicus,* new species 14
The holotype, × 4, incrusting a *Chonetes,* exhibiting the short, quickly tapering ambulacra.
Devonian (Long Lake beds of Presque Isle formation): Quarry, Alpena Portland Cement Co., Alpena County, Michigan.

Fig. 2. *Hemicystites* (*Agelacrinites*) *latiusculus* (Barrande) 11
Well-preserved example, × 2.
Ordovician (D4): Zahorzan, Bohemia.

Figs. 3, 4. *Hemicystites* (*Agelacrinites*) *bohemicus* (Barrande) 11
A large distorted specimen and a small, more perfect individual, × 1.
Ordovician (D2): Mount Drabow, Bohemia.

Fig. 5. *Hemicystites* (*Agelacrinites*) *confertus* (Barrande) 11
Theca, × 1.6, with marginal plates little developed.
Ordovician (D2): Mount Drabow, Bohemia.

Fig. 6. *Hemicystites* (*Agelacrinites*) *simplex* (Barrande) 11
A species similar to the preceding but with well-developed marginal rows, × 2.
Ordovician (D4): Zahorzan, Bohemia.

Fig. 7. *Lepidodiscus milleri* Sharman and Newton 20
Specimen, × 3, showing the generic characters clearly.
Subcarboniferous: Waterhead, Cumberland, England.

Fig. 8. *Lepidodiscus* (*Agelacrinites*) *buttsi* (Clarke) 20
Type specimen, × 1.3, with broad marginal area.
Mississippian (between Wolf Creek conglomerate and Mount Hermon sandstone): Cattaraugus County, New York.

Fig. 9. *Agelacrinites* (*Agelacrinus*) *blairi* (Miller) 16
Photograph of the holotype, × 4, attached to arms of a batocrinid.
Mississippian (Warsaw): Boonville, Missouri.

Fig. 10. *Agelacrinites hanoveri* Thomas 16
One of the types, × 4, a small individual with broad marginal rim.
Devonian (Shell Rock): Mason City, Iowa.

Fig. 11. *Discocystis* (*Agelacrinites*) *kaskaskiensis* (Hall) 21
(See also pl. 1, figs. 4, 5; pl. 3, figs. 4-6.)
Basal view of theca, × 2, showing central opening and many rows of closely packed marginal plates.
Chester (Glen Dean): Sloans Valley, Kentucky.

Fig. 12. *Isorophusella* (*Lebetodiscus*) *incondita* (Raymond) 19, 20
A specimen from the type slab, × 4, showing slightly curved rays and broad oral area.
Trenton (Cystid bed): Ottawa, Ontario.

Fig. 13. *Foerstediscus splendens,* new species 10
Holotype, × 4, illustrating the dextrally curved rays, mosaic interambulacrals, and tubelike anal area of this striking species.
Black River (Decorah shale, top of *Rhinidictya* bed); Ford plant, St. Paul, Minnesota.

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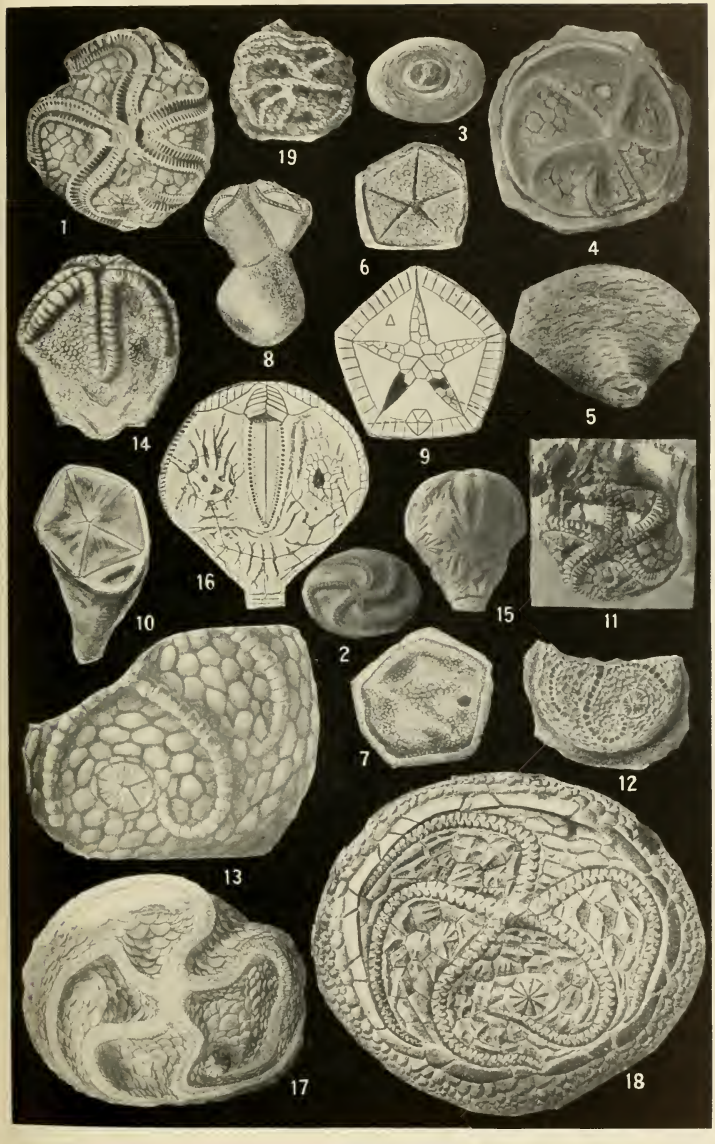
FIG. 14. *Xenocystites carteri,* new genus and species..... 3
The type specimen, × 1.6, half of a theca showing basal covering plates and the outlines of four ambulacra impressed upon them.
Chemung (Gowanda): Cattaraugus Creek, Versailles, New York.

FIG. 15. *Carneyella ?* (*Lebetodiscus*) *platys* (Raymond)..... 7
Photograph of the type specimen, × 4.
Middle Trenton, Ottawa, Canada.



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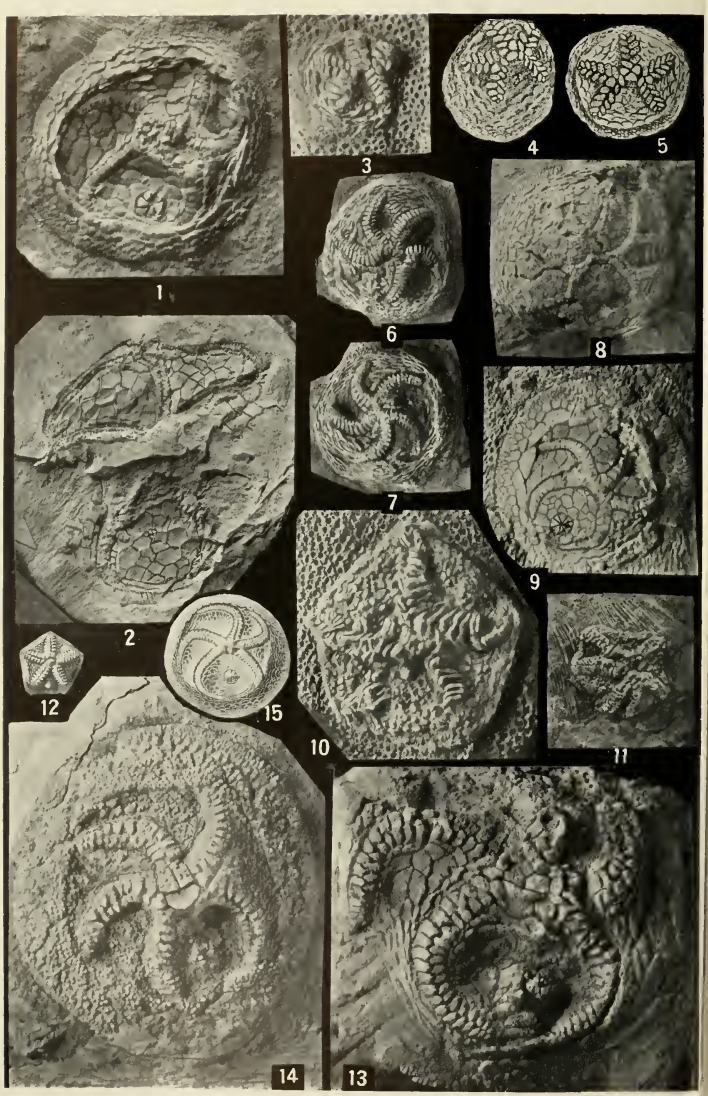
(For explanation, see pages 25, 26.)



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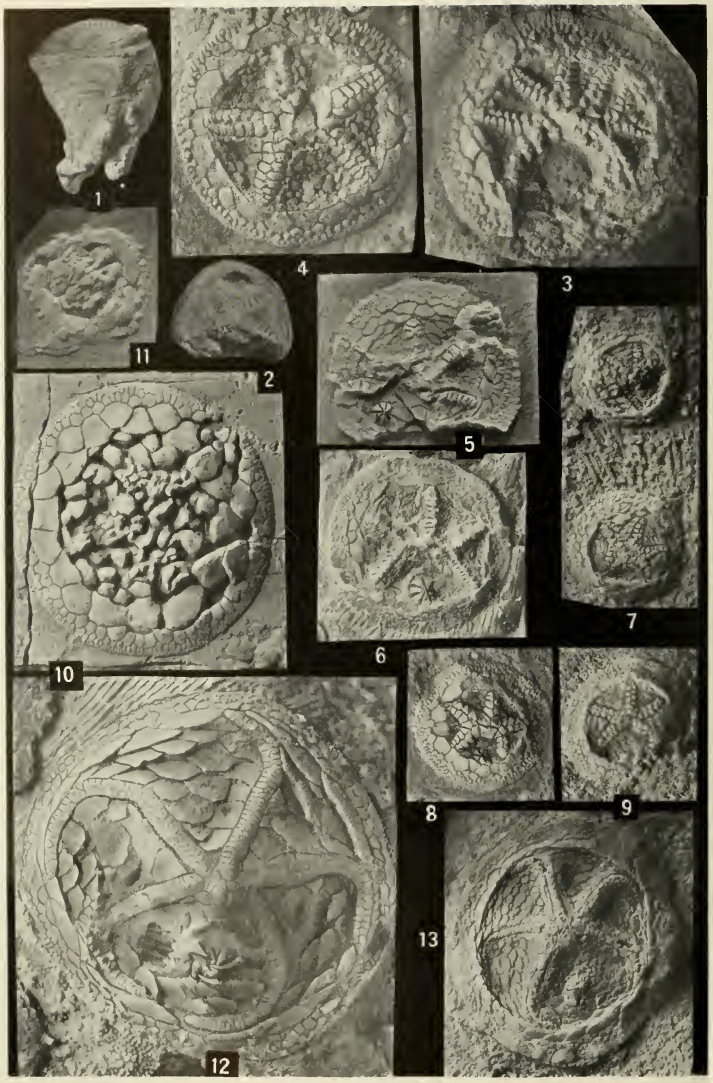

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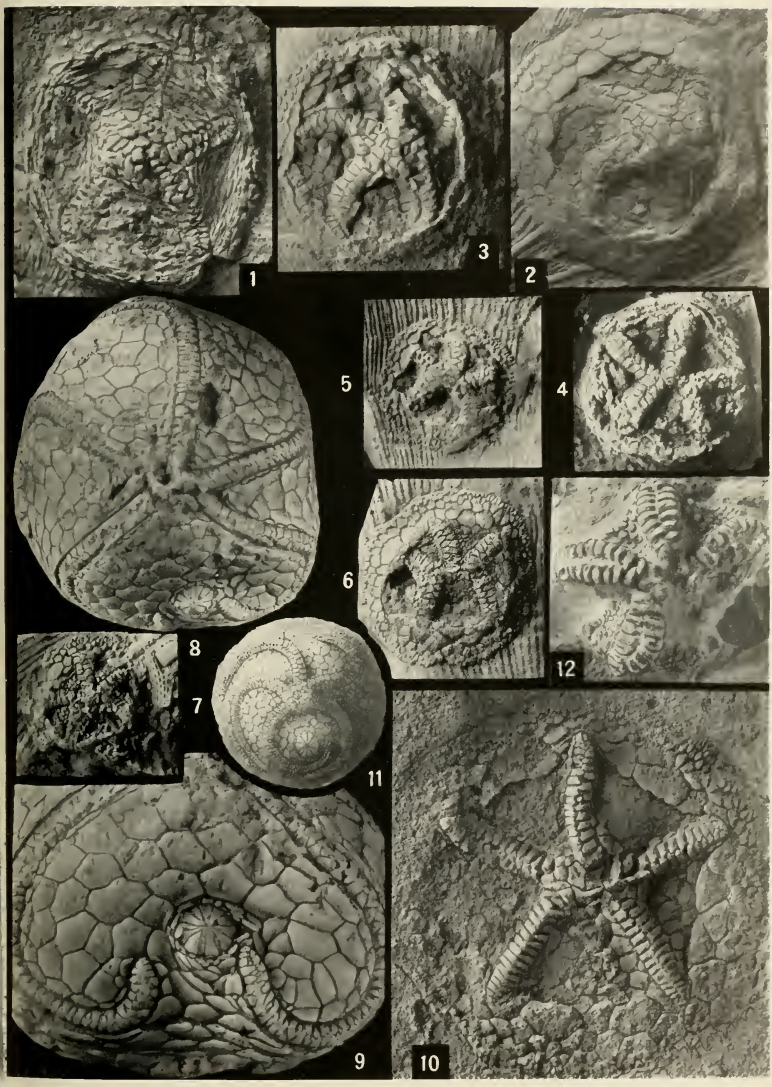

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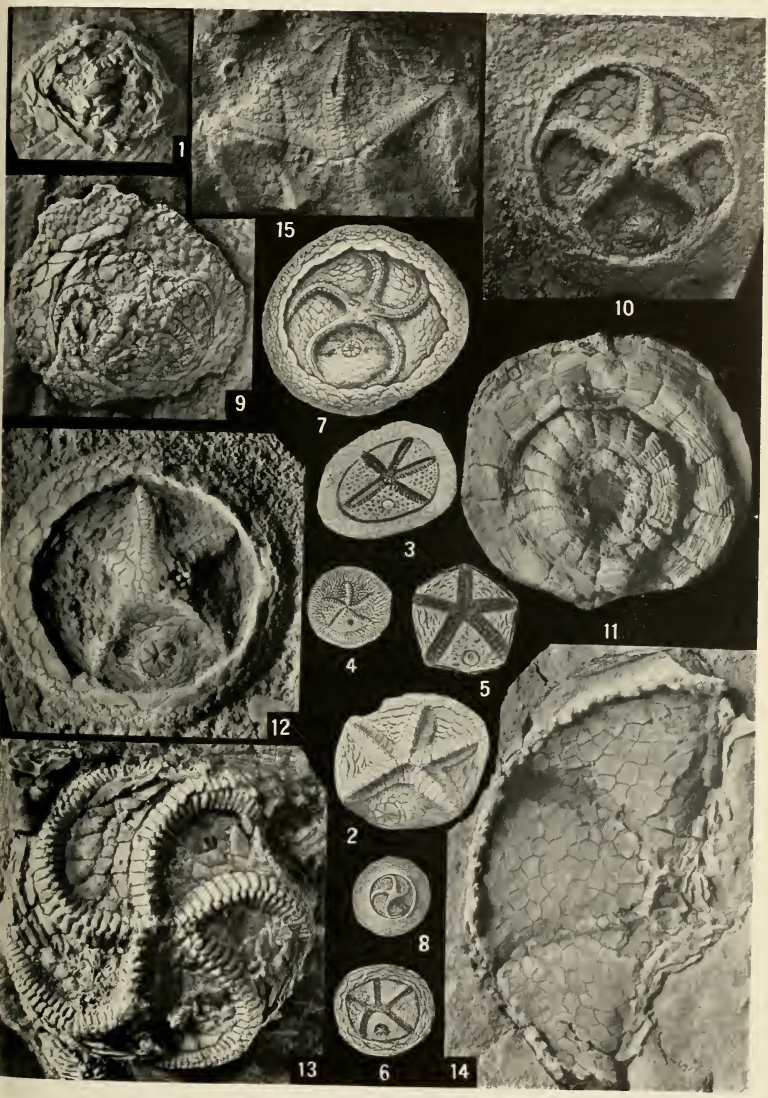

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