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EXPLOSIVE EVOLUTIONARY DIFFERENTIATION OF  
UNIQUE GROUP OF MISSISSIPPIAN-PENNSYLVANIAN  
CAMERATE CRINOIDS (ACROCRINIDAE)

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ABSTRACT

Crinoids classed as constituents of the family Acrocrinidae are distinguished from all other Camerata, as well as representatives of remaining subclasses, in having circlets of supplemental calyx plates between the bipartite basals and ring of radials and single primanal at summit of the calyx. The supplemental plates, designated as intercalaries, range in number from six to 600 or more. Analysis of their arrangement, combined with other characteristics, furnishes morphological grounds for differentiation of several genera instead of a single one (*Acrocrinus*), which until now has been considered to be the sole generic component of the family. All of the newly recognized acrocrinid genera and seven new species assigned to three of them are determined on seemingly firm and significant distinctions. The whole assemblage demonstrates remarkable evolutionary changes along different lines, which are expressed in calyx shape, attitude of the basal plates, number and positions of the arms, features of the tegmen, and especially by an explosively rapid increase in number of intercalary plates to a Late Mississippian peak, great decline in the Pennsylvanian, and by diverse patterns of distalmost intercalaries. Two subfamilies are recognized but their interrelations and phylogenetic lines are very obscure.

INTRODUCTION

Around the middle of the last century, approximately 125 years ago, some unique fossil crinoids were discovered by L. P. YANDELL and B. F. SHUMARD in western Kentucky (Grayson County) about 75 miles southwest of Louisville. They were obtained from strata then called Lower Carboniferous and now classed as Upper Mississippian (Chesteran). Among these fossils were at least one flattened incomplete crown with a short section of attached stem and specimens consisting of parts of calices. Later deposited in a museum in Louisville, the calyx with remnant portion of arms has a height of 80 mm. (3.25 in.) and maximum calyx width of 30 mm. (1.2 in.). Based on comparison with other complete crowns, this specimen had an original height of at least 160 mm. (6.5 in.). A platyceratid snail 40 mm. tall

and nearly as wide at its base as the entire space between arm bases is fixed to the crinoid's tegmen.

The most distinctive feature of the calyx is the construction of its side walls, formed by hundreds of small polygonal plates arranged in well- to ill-defined circlets, instead of the very modest number of calyx plates found in most crinoids. Next beneath the branched free arms in each of the five rays is a very wide, low radial plate, and although not shown in the first-found flattened crown, a sixth plate shaped like the radials but without attached arms is interposed in the radial circlet. This plate now is designated as primanal. At the bottom of the calyx are two relatively large basal plates with steeply upsloping outer margins. They are equal in size and divided by a straight suture. The small polygonal plates between the

basals and radials are called intercalaries. They are arranged in approximately 20 to 25 circlets and in aggregate number are roughly 600 to 700. The round stem is composed of low circular discs.

The previously mentioned specimen with attached gastropod was illustrated by YANDELL & SHUMARD in 1847 (pl. 1, fig. 3) without an accompanying name and without description, except for mention (p. 25) of its extraordinarily numerous calyx plates. Eight years later, YANDELL (1855) published a larger and improved drawing of the specimen figured in the 1847 paper and with it a diagnosis of the crinoid as representative of a new genus named *Acrocrinus*. The type species (by monotypy) was designated *A. shumardi*. Affinity of *Acrocrinus* with *Platycrinus* (*recte Platycrinites*) was suggested because of its bipartite basal circlet, although the three-basal circlet of *Platycrinites* is not at all comparable to that of *Acrocrinus*. No family assignment for the new genus was suggested.

A curious irrelevant item is the statement by YANDELL (p. 136) that the large gastropod fastened to the tegmen of the crinoid is truly recognizable as prey of the crinoid "in a position to have been grasped by the arms of the living animal . . . [which] was probably devouring the shell-fish at the time when it perished." This was thought to be borne out by the observation that "we have found numerous specimens of encrinites with univalve mollusca in a similar position"—observation correct but interpretation wrong, for now no one doubts that the gastropod-crinoid association is explained by the gastropod's selection of a crinoid host which after attachment of the snail to its tegmen willy-nilly yields its fecal waste for sustenance of the gastropod (BOWSHER, 1955).

In 1858, HALL (p. 690, pl. 25, fig. 9a-b) figured and very briefly described a crinoid "with base divided on one side" and superjacent lower sides of the calyx composed of numerous tiny polygonal plates not arranged in regular circlets. Because of incompleteness of this fossil, the nature of the summit portion of the calyx, as well as that of the arms and stem was unknown. HALL assigned the specimen to a new species named *Acrocrinus urnaeformis*, which, despite recognition by WACHSMUTH & SPRINGER (1885, p. 125) and subsequently by SPRINGER (1926, p. 44), is considered insufficiently distinct from *A. shumardi* for treatment other than as a synonym of the

latter species (WACHSMUTH & SPRINGER, 1897, p. 806; BASSLER & MOODEY, 1943, p. 266). *A. urnaeformis* occurs in Upper Mississippian (Chesteran) strata now classed as Paint Creek Formation, in Pope County, southernmost Illinois.

The family Acrocrinidae was proposed by WACHSMUTH & SPRINGER in 1885 (p. 120) for reception of the single genus, *Acrocrinus*. These authors reaffirmed the family-group assemblage in 1897 (p. 803) with an accompanying diagnosis which noted its morphological resemblance to the Hexacrinidae except for possession of numerous circlets of intercalary plates. The acrocrinids were presumed to be descendants of hexacrinid ancestors. BATHER (1899, p. 921) mentioned the Acrocrinidae in his phylogenetic classification of Pelmatozoa but did not cite them in *The Echinoderma* (BATHER, 1900). MOORE & LAUDON (1943, p. 96) published a characterization of the family and of *Acrocrinus*, concluding that crinoids of this group were derived from the Dichocrinidae, which also have two equal basals. UBAGHS (1953, p. 740-741) placed *Acrocrinus* in a subfamily (Acrocrininae) of the Dichocrinidae, along with genera grouped in the Dichocrininae and a newly defined subfamily named Talarocrininae.

Studies of new Pennsylvanian acrocrinids planned for inclusion in two papers on assemblages of Morrowan and Missourian crinoids have led us to examine morphological features of all previously reported members of the family, comparing these with each other and with the new forms in our collections. Despite very noteworthy differences in calyx shape, attitude and relative prominence of the basal plates, outlines of the radial plates with notice of great height-to-width variation in their dimensions and especially of the nature of their articular facets, and range in number of intercalary plates from six to more than 600, all acrocrinids heretofore described have been assigned to the genus *Acrocrinus*. Moreover, the arrangement of intercalaries, features of the arms, and structures of the tegmen have been overlooked very largely. The possible taxonomic significance of each mentioned morphological distinction has failed to receive attention. Consequently, this paper is the first to offer comparative analyses of the entire assemblage of crinoids assignable to the Acrocrinidae as known to this date. Quite unanticipated at outset of the study has been an expansion of the family to a content of ten genera grouped in two subfamilies. They

take the place of a single all-embracing genus named *Acrocrinus*. The new classification of these unique Mississippian-Pennsylvanian camerate crinoids reflects the remarkable evolutionary

differentiation displayed by them in a short span of late Paleozoic time. In so far as known, the stock did not persist beyond early Late Pennsylvanian.

## SYSTEMATIC PALEONTOLOGY

### Family ACROCRINIDAE Wachsmuth & Springer, 1885

[Acrocrinidae WACHSMUTH & SPRINGER, 1885,  
p. 120 (342)]

DIAGNOSIS.—Crown ovoid to pyriform, with height exceeding greatest width; arms (where known) erect or pendent, mostly biserial, but may be wholly or in part cuneate uniserial, well rounded externally, pinnulate. Calyx subconical, vase-like, tall ovoid, or subglobular, with two equal basals separated by suture between them oriented anteroposteriorly as in Dichocrinidae; radials five, laterally adjoining one another except *C* and *D* radials, which are separated by primanal (*X*) plate; radials and basals not in contact but set apart by few to very many intervening supplementary plates collectively designated as intercalaries; tegmen flat to gently convex, with or without differentiated orals and having few or extremely numerous small plates, anal vent near posterior margin, inconspicuous or located at tip of anal pyramid, stem transversely circular, homeomorphic or heteromorphic, with columnar articular facets peripherally crenulate; axial canal diminutive, circular to distinctly pentalobate or stellate in section, with narrow sharp-tipped rays oriented interradially. [The outstanding attribute of this family is the presence of intercalaries in calices of all genera. These may be arranged in moderately regular alternating circlets or appear quite irregular, with proximal plates notably smaller than distal ones. The advent of intercalaries in a late Paleozoic group of camerate crinoids suggests evolutionary reversion to a cystoidlike structure of the calyx and divergence of genera in significant morphological features indicates unusual plasticity of the stock.] *Lower Mississippian (Kinderhookian) to Upper Pennsylvanian (Missourian); Upper Lower Carboniferous to Middle Carboniferous.*

DISCUSSION.—Up to the present time 12 species of crinoids from Mississippian and Pennsylvanian

formations of North America have been classed as belonging to *Acrocrinus* and two additional ones have been reported from Lower and Upper Carboniferous rocks of Europe. These have been reckoned to comprise the entire assemblage included in the family Acrocrinidae or according to UBAGHS (1953, p. 741) in the subfamily Acrocrininae, placed with so-called Dichocrininae and Talarocrininae in the family Dichocrinidae. The single diagnostic characteristic of *Acrocrinus* and the Acrocrinidae has been judged to be the presence of circlets of supplemental plates between the two equal basals joined to the transversely circular stem and five subequal radials at the summit of the calyx. The supplemental plates, called intercalaries, are extremely numerous in some species, including *A. shumardi*, type species of the genus, but comparatively few to very few in others. A critical review of all previously described forms referred to *Acrocrinus* and study of new ones which we initially thought should be assigned to the genus have called attention to several morphological distinctions which in our opinion warrant division of the old and new species into separate genera. These can be grouped desirably in two subfamilies.

The characteristics which we judge to be significant for generic differentiation include: 1) nature of the radial articular facets, in particular their width, shape, and attitude; 2) upflaring or peripherally upturned basals clearly visible in side views of the calyx, as opposed to their entirely horizontal attitude and invisibility in side views; 3) number and positions of plates in the distalmost circlet of intercalaries; 4) features of the tegmen where determinable, with presence of absence of distinct orals and anal pyramid; and 5) upright or pendent arms. Using these criteria (calyx structure illustrated in Figure 1), the ten genera (nine new) described in this paper can be distinguished. The revised classification of acrocrinids is summarized in the following tabulation.

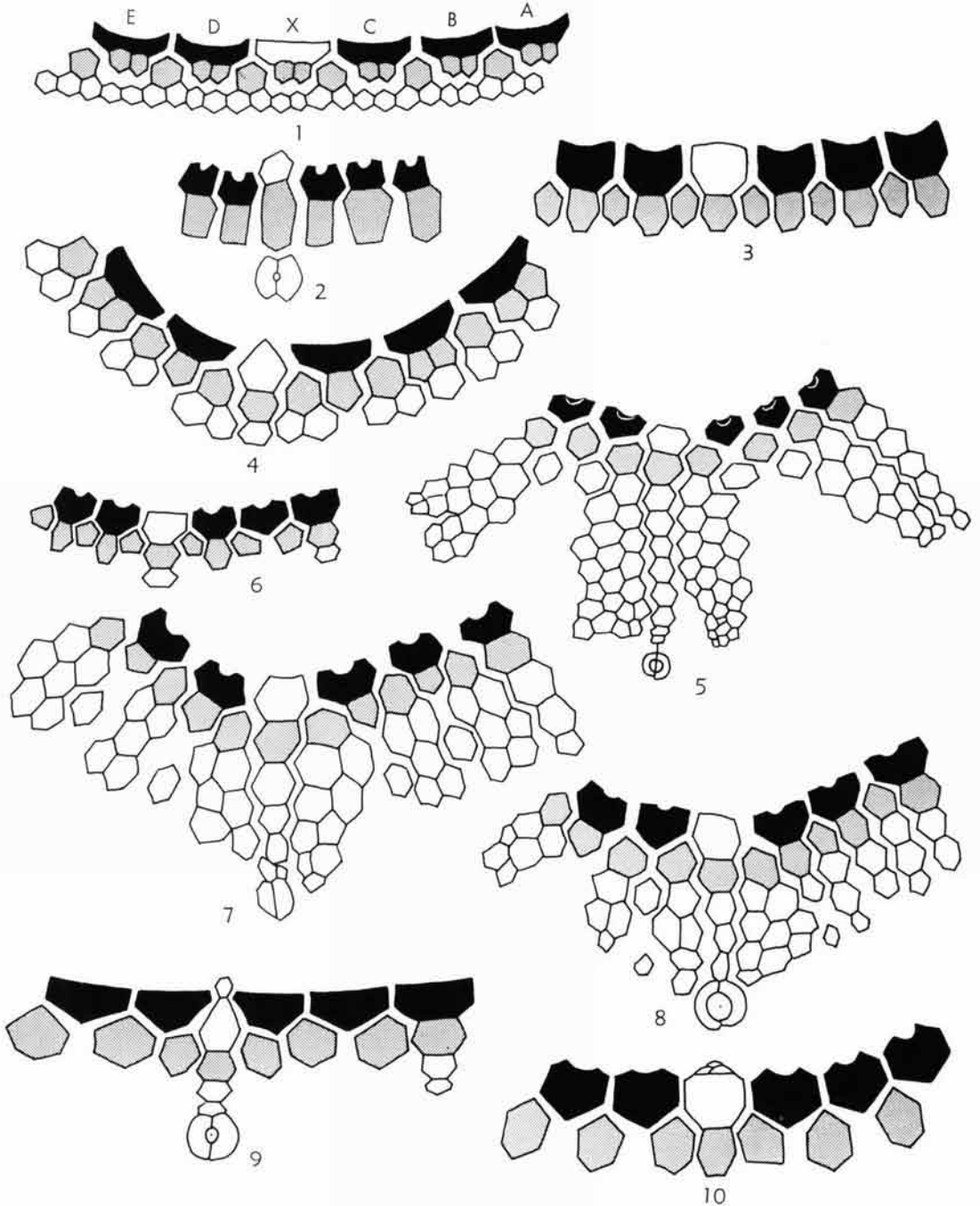


FIG. 1. Diagrams of acrocrinid plate structure, especially in upper part of calyx (continued on facing page).

[EXPLANATION.—Radials solid black; primanal (X) plate letters A-E for designations of rays in the W. B. Carpenter system (same in all diagrams); distalmost intercalary plates shaded gray, others and bipartite basal circling unshaded. Not to scale.]

1. *Acrocrinus* YANDELL (based on type species, *A. shumardi*), characterized by very wide low radials and primanal, articular facets of radials occupying entire distal margin of plate, 18 intercalaries in distalmost circling with two of these beneath each radial and primanal.

Subfamilies and Genera of Acrocrinidae with  
Assignment of Species

- Acrocrininae Wachsmuth & Springer, 1885, U.Miss. (Chester.)—L.Penn. (Morrow.)
- Acrocrinus* Yandell, 1885, U.Miss. (Chester.), L.Carb. (Viscan)
- Acrocrinus shumardi* Yandell, 1855 (type species), Up.Chester.  
[=*Acrocrinus urnaeformis* Hall, 1858]
- Acrocrinus alvestonensis* Wright, L.Carb. (Viscan)
- Amphoracrocrinus* Moore & Strimple, n. gen., U.Miss. (Chester.)
- Amphoracrocrinus amphora* (Wachsmuth & Springer), 1897 (type species), Low.Chester.
- Platyacrocrinus* Moore & Strimple, n. gen., L.Penn. (Morrow.)
- Platyacrocrinus brentwoodensis* (Moore & Plummer), 1938 (type species), Brentwood Ls.
- Planacrocrinus* Moore & Strimple, n. gen., L.Penn. (Morrow.)
- Planacrocrinus ambix* Moore & Strimple, n. sp. (type species), L.Penn. (Morrow.), Wapanucka Ls.
- Planacrocrinus conicus* Moore & Strimple, n. sp., L.Penn. (Morrow.), Brentwood Ls.
- Planacrocrinus minutus* Moore & Strimple, n. sp., L.Penn. (Morrow.), Brentwood Ls.
- Globacrocrininae Moore & Strimple, n. subfam., L.Miss. (Kinderhook.)—U.Penn. (Missouri.), M.Carb. (Mos-cov.)
- Globacrocrinus* Moore & Strimple, n. gen., L.Miss. (Osag.)—M.Penn. (Desmoines.)
- Globacrocrinus pirum* (Moore & Plummer), 1937 (1938) (type species), L.Penn. (Morrow.), Brentwood Ls.
- Globacrocrinus glomus* Moore & Strimple, n. sp., M.Penn. (Desmoines.), Oologah Ls.
- Globacrocrinus rotundus* Moore & Strimple, n. sp., L.Penn. (Morrow.), Wapanucka Ls.

- Caucacrocrinus* Moore & Strimple, n. gen., U.Penn. (Missouri.)
- Caucacrocrinus urnula* Moore & Strimple, n. sp. (type species), U.Penn. (Missouri.), LaSalle Ls.
- Caucacrocrinus acutus* Moore & Strimple, n. sp., U.Penn. (Missouri.), LaSalle Ls.
- Dinacrocrinus* Moore & Strimple, n. gen., M.Penn. (Desmoines.)—U.Penn. (Missouri.)
- Dinacrocrinus expansus* (Strimple), 1951 (type species), M.Penn. (Desmoines.), Oologah Ls.
- Dinacrocrinus elegans* (Strimple), 1949, U.Penn. (Missouri.), Ochelata Gr.
- Dinacrocrinus wortheni* (Wachsmuth), 1882, U.Penn. (Missouri.)
- Metacrocrinus* Moore & Strimple, n. gen., M.Penn. (Desmoines.)
- Metacrocrinus pumpkensis* (Strimple), 1949 (type species), M.Penn. (Desmoines.), Dornick Hills Fm.
- Protacrocrinus* Moore & Strimple, n. gen., L.Miss. (Kinderhook.)
- Protacrocrinus primitivus* (Laudon & Beane), 1937, L.Miss. (Kinderhook.), Hampton Fm.
- Springeracrocrinus* Moore & Strimple, n. gen., L.Miss. (Osag.)—U.Miss. (Chester.), M.Carb.
- Springeracrocrinus intermedius* (Springer), 1926 (type species), U.Miss. (Chester.)
- Springeracrocrinus mjaschkowensis* (Yakovlev), 1926, M.Carb. (Moscov.)
- Springeracrocrinus praecursor* (Springer), 1926, L.Miss. (Osag.)

The outline just given expresses a taxonomic diversity of acrocrinids far greater than was anticipated by us when studies of undescribed fossils from Lower, Middle, and Upper Pennsylvanian sources in our collections began. It is now evident that additional materials and thorough investiga-

- Protacrocrinus* MOORE & STRIMPLE, n. gen. (based on type species, *P. primitivus*), distinguished by presence of only six intercalary plates.
- Amphoracrocrinus* MOORE & STRIMPLE, n. gen. (based on type species, *A. amphora*), resembling *Acrocrinus* in wide articular facets of radials, but having single intercalary beneath each radial and primanal, with total of 12 intercalaries in distalmost circlet.
- Platyacrocrinus* MOORE & STRIMPLE, n. gen. (based on type species, *P. brentwoodensis*), radial articular facets occupying entire distal margin of these plates, 15 intercalaries in distalmost circlet.
- Globacrocrinus* MOORE & STRIMPLE, n. gen. (based on type species, *G. pirum*), with narrow arcuate radial articular facets and eight distalmost intercalaries.
- Caucacrocrinus* MOORE & STRIMPLE, n. gen. (based on type species, *C. urnula*), distinguished by calyx shape with upsloping basals, radial facets as in *Globacrocrinus*, and 11 distalmost intercalaries.
- Dinacrocrinus* MOORE & STRIMPLE, n. gen. (based on type species, *D. expansus*), basals not visible in side view of calyx, 12 distalmost intercalaries.
- Metacrocrinus* MOORE & STRIMPLE, n. gen. (based on type species, *M. pumpkensis*), lacking *D*-ray subradial intercalary, 11 of these plates in distalmost circlet.
- Planacrocrinus* MOORE & STRIMPLE, n. gen. (based on type species, *P. ambix*), resembling *Caucacrocrinus* in calyx shape and upflared basals, but with wide radial articular facets, eight distalmost intercalaries.
- Springeracrocrinus* MOORE & STRIMPLE, n. gen. (based on type species, *S. intermedius*), lacking any subradial intercalary in distalmost circlet of these plates, containing seven in all.

tions of them are needed to provide understanding of the evolutionary origin of various observed morphologic features, to test the validity of species, genera, and subfamilies within this remarkably plastic assemblage, as well as to distinguish the phylogeny of different lineages. One hardly can doubt that the Acrocrinidae are descendants of dichocrinid ancestors, even though earliest known species of *Dichocrinus* are little older than *Protacrocrinus primitivus* and *Springeracrocrinus praecursor*.

*Protacrocrinus* is both the oldest and the simplest acrocrinid known. Possibly, but by no means certainly, it is ancestral to all other genera of the family. The correctness of including it in the Acrocrinidae is unquestioned, since all essential morphological features of the calyx—five radials and primanal in the topmost cirlet, presence of intercalary plates, and bipartite nature of the basal cirlet with suture oriented anteroposteriorly—and the biserial structure of its pinnule-bearing branched arms are diagnostic characteristics. Little evolutionary change is needed to yield *Springeracrocrinus*, for this involves only a shift of all distalmost intercalaries to interradian locations and addition of a varying number of intercalary plates between them and the basals. The next most similar acrocrinid, however, is *Caucacrocrinus*, with narrowly arcuate radial facets, upflaring basals, and a larger number of distalmost intercalaries. In spite of the fact that this genus is the youngest (Upper Pennsylvanian) of all known representatives of the family, it could be a direct lineal derivative of *Springeracrocrinus* and *Protacrocrinus*. If true, other members of the Globacrocrininae, all of which (with possible exception of *Dinacrocrinus wortheni*) occur in Lower or Middle Pennsylvanian formations, would have to be interpreted as side branches of the acrocrinid phylogenetic tree, collectively marked by the horizontal attitude of their basal cirlets, invisible in side views of the calyx.

The origin of the Acrocrininae, characterized by very wide radial articular facets and prevalently (if not exclusively) upflaring basals is entirely conjectural. All presently known genera of this subfamily are confined to Upper Mississippian or Lower Pennsylvanian deposits. In *Acrocrinus* (Chesteran) we find the maximum number of intercalary plates (possibly 600 or 700) and largest number of distalmost intercalaries (18). Pennsylvanian genera display a greatly

reduced total complement of intercalaries and distalmost ones ranging from eight to 15. Accordingly, in this group maximum complexity of calyx organization was preceded by comparatively simple structure and was followed by very notable diminution of calyx components. Assuming that all genera here recognized as members of the Acrocrinidae belong together as a natural phyletic group, evolution of different stocks seemingly must be interpreted as embracing an explosive accentuation of "acrocrinid" morphological characteristics developed from an extremely simple initial stage, followed by reversion to relative simplicity of structure. The peak of complexity was attained approximately midway (Late Mississippian) in the life history of the assemblage.

### Subfamily ACROCRININAE Wachsmuth & Springer, 1885

[*nom. transl.* UBAGHS, 1953, p. 741 (ex Acrocrinidae WACHSMUTH & SPRINGER, 1885, p. 120)]

DIAGNOSIS.—Calyx tall urn-shaped to medium low bowl-shaped, chiefly characterized by very wide low radials or with these plates moderate in height, all with straight to gently scalloped articular facets occupying entire distal margin; primanal (X) plate in cirlet of radials and similar to them in shape or subpentagonal in outline, narrowing upward; basals upflaring, clearly visible from side; intercalaries in few to numerous (2 to 25) well- or ill-defined cirlets and ranging in aggregate number from 10 or 15 to as many as 700, distalmost cirlet containing 7, 8, 11, 12, 15, or 18 plates, of which seven (including subanals) invariably are located interradianly (eight in *Acrocrinus*) and others radially; tegmen formed by few to extremely numerous plates, with or without differentiated orals, lacking observed anal pyramid. Arms erect or pendent, composed of biserial, pinnule-bearing brachials. *Upper Mississippian (Chesteran) to Lower Pennsylvanian (Morrowan), or Upper Lower Carboniferous (Visean).*

DESCRIPTION.—Genera and species brought together in this subfamily include much the largest of all known acrocrinids, with height of calyx ranging from 20 to more than 50 mm. and calyx width of approximately 15 to 30 mm. The highly pinnulate biserial arms of best-preserved specimens may appreciably exceed in their length the total height of the calyx. The arms are unbranched

above bifurcations close to the summit of the calyx, and their number in each ray commonly is four, six, or eight. The Acrocrininae are mostly distinguished from the new subfamily named Globacrocrininae by their exceptionally large number of intercalaries in walls of the calyx, for individuals of *Acrocrinus* display at least 400 and may have more than 600 such plates. In *Amphoracrocrinus* intercalaries range in number from about 300 to 500. On the other hand, *Platyacrocrinus* probably has a maximum of little more than 100 intercalaries. In *Planacrocrinus*, on the other hand, intercalaries are exceptionally few (commonly only 15 to 40). This genus is included in the Acrocrininae because the shape and width of its radial articular facets are like those of other genera here brought together in the subfamily and its primanal allies it with *Platyacrocrinus*.

The dimensions of some, but not all species described in this paper, are given compactly by use of the letters D (diameter), H (height), L (length), T (thickness), and W (width), all stated in millimeters.

### Genus ACROCRINUS Yandell, 1855

[*Acrocrinus* YANDELL, 1855, p. 135]

TYPE SPECIES.—*A. shumardi* YANDELL, 1855; by monotypy.

DIAGNOSIS.—Calyx urn-shaped, with unusually low, wide radials and primanal; distal articular facet of radials supporting minute axillary primibrach 1 and 2 secundibrachs 1, latter followed by axillary secundibrach 2; most distal circlet of intercalaries including 10 small subradials and 8 in interradian positions, those of CD interray comprising 2 small subanals and 2 distinctly larger intercalaries next to them on either side. Arms erect. Stem homeomorphic, composed of very low columnals (Fig. 1, J). *Upper Mississippian (Chesteran)*, North America (USA) and *Upper Lower Carboniferous (Visean)*, Europe (England).

#### ACROCRINUS SHUMARDI Yandell

*Acrocrinus shumardi* YANDELL, 1855, p. 135, fig.—WACHSMUTH & SPRINGER, 1897, p. 806, pl. 80, fig. 1-3.—SPRINGER, 1926, p. 45, pl. 12, fig. 6-7.  
*Acrocrinus urnaeformis* HALL, 1858, p. 690, pl. 25, fig. 9a-b.

DIAGNOSIS.—Characters of genus.

DESCRIPTION.—The height of the elongate calyx (51 mm. in the large holotype specimen) is approximately twice its greatest width, although in the figure given by WACHSMUTH & SPRINGER (1897, pl. 80, fig. 1) the width appears to be exaggerated (30 mm.) by flattening. According to R. S. BASSLER (personal communication to R. C. MOORE), the cited illustration is natural size. It shows excellently the subequal small smooth-surfaced intercalaries, basal circlet without indication of the anteroposterior interbasal suture, and 3 radials with proximal parts of attached arms. The rays to which the radials belong are not identifiable beyond observation that none are seen to adjoin the primanal, thus indicating that they could be radials of the A-B-C, D-E-A, or E-A-B rays. The height of the radials (3 mm.) is one-fourth of their width (12 mm.) and height of the basal circlet (2.8 mm.) a little more than one-third of its greatest width (7.5 mm.). A diminutive but nearly perfect crown figured by SPRINGER (1926, pl. 12, fig. 6) has a calyx height of 13 mm., calyx width of 9 mm., and height of arms amounting to 29 mm.; part of the attached slender stem has a diameter of 2 mm.

ILLUSTRATIONS.—FIG. 1, J. Diagram showing plate arrangement in summit portion of calyx (broad-faceted radials black, distalmost intercalaries gray) showing 2 subradial intercalary plates in all rays and 2 subanal ones in CD interray, others interradian, 18 in entire circlet.—FIG. 2, J, 2. Oblique view of lower part of calyx showing bipartite basal circlet beneath irregularly arranged small intercalaries, and lateral view of crown (holotype) with attached proximal part of stem (rays not identified),  $\times 2$ ,  $\times 1$  (both specimens from Glen Dean Limestone in Sloan's Valley, Pulaski County, Kentucky (Wachsmuth & Springer, 1897)).—FIG. 2, 3. Side view of small crown (rays not identified),  $\times 1.5$  (from Glen Dean Limestone at Grayson Springs, Grayson County, Kentucky) (Springer, 1926).

TYPES.—Holotype (location of YANDELL's type not determined). Hypotypes (Fig. 2, J), S1584, U. S. National Museum; (Fig. 2, 3) S1583 USNM.

OCCURRENCE.—Upper Chester Group in Breckinridge, Grayson, and Pulaski Counties, Kentucky; Glen Dean Limestone, upper Chesteran, Madison County, Alabama; Paint Creek Formation, middle Chesteran, Pope County, Illinois; all Upper Mississippian.

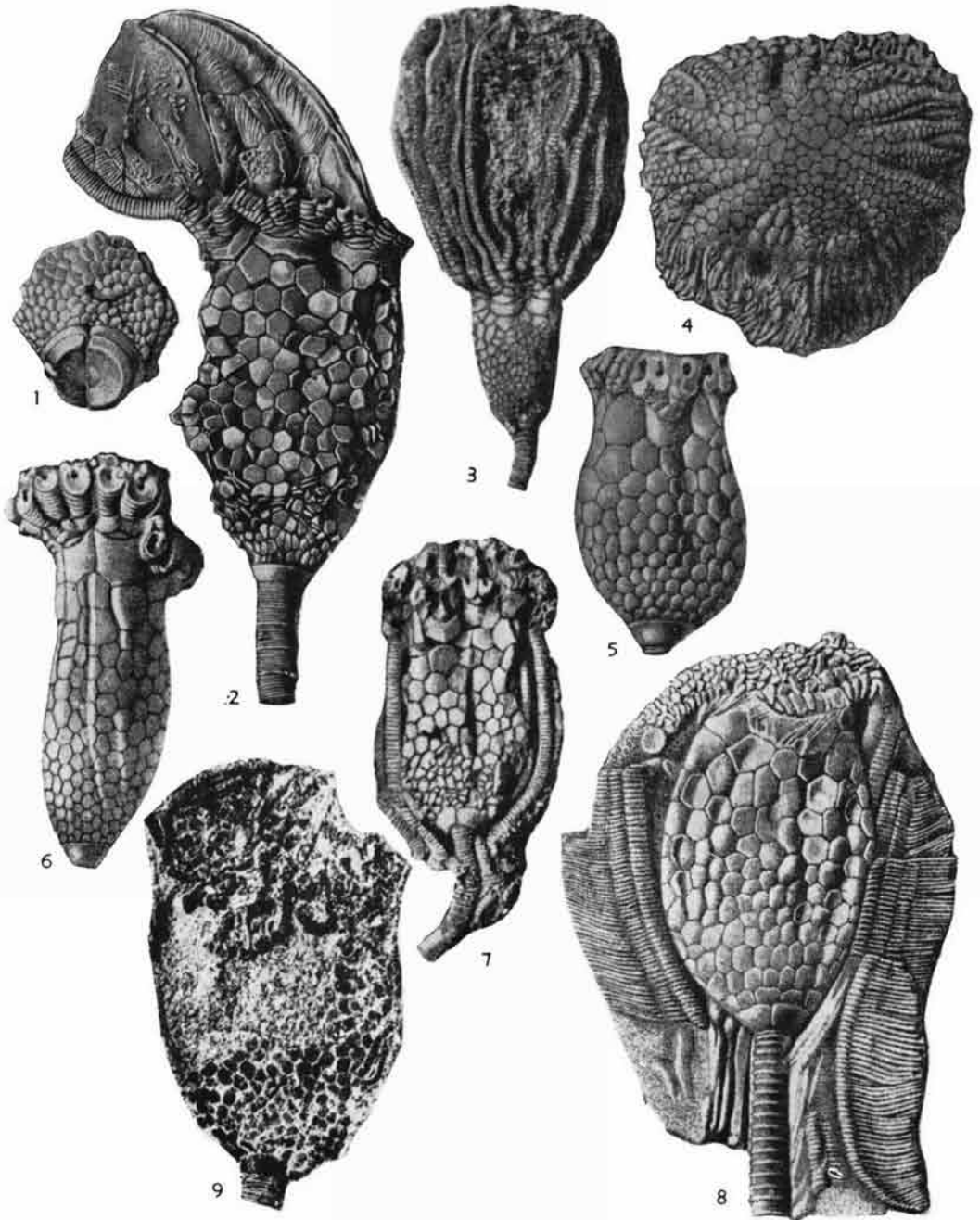


FIG. 2. *Acrocrinus* YANDELL and *Amphoracrocrinus* MOORE & STRIMPLE, n. gen. (continued on facing page).

1-3. *Acrocrinus shumardi* YANDELL; 1, oblique view of lower part of calyx clearly showing two equal basals with upflared margins and superjacent small intercalaries not arranged in distinct circlelets,  $\times 2$ ; 2, holo-type specimen, with most of arms broken away, their bases surrounding large curved-conical shell of capulid

gastropod which occupies nearly entire area of the tegmen,  $\times 1$ ; 3, small crown with erect arms and attached portion of stem,  $\times 1.5$ .

4-8. *Amphoracrocrinus amphora* (WACHSMUTH & SPRINGER), MOORE & STRIMPLE, n. comb.; 4, tegmen of specimen, *CD* interray with anal orifice directed downward,



**ACROCRINUS ALVESTONENSIS** Wright

*Acrocrinus alvestonensis* WRIGHT, 1958, p. 308, pl. 79, fig. 1-4.

DIAGNOSIS.—Very similar to *Acrocrinus shumardi* in all discernible features but only about one-half as large.

DESCRIPTION.—Abundant small intercalaries subequal in size throughout most of calyx height, not arranged in well-defined circlets; width of calyx (17 mm.) 70 percent of height (24 mm.), height of basal circlet (1.5 mm.) one-third of greatest width (4.5 mm.); stem 4-5 mm. in diameter composed of very low columnals, uniform in appearance throughout proximal portion equal to 3 times height of calyx. Arms round, slender, erect and somewhat outspread, number to ray undetermined.

ILLUSTRATION.—FIG. 2,9. Holotype, a crushed incomplete crown,  $\times 1.5$  (Wright, 1958).

DISCUSSION.—This species is based on 3 fairly complete but badly squeezed crowns, 2 with long attached proximal part of the stem. The assignment of the fossils to *Acrocrinus* seems to be well founded and of interest is their approximate equivalence in age to *A. shumardi*.

TYPES.—Holotype, Geological Survey and Museum (London), 5091a; paratype, same, 5091b.

OCCURRENCE.—Upper Lower Carboniferous (Visean), S<sub>2</sub> Subzone, Gloucestershire, south-western England.

**Genus AMPHORACROCRINUS** Moore & Strimple, n. gen.

TYPE SPECIES.—*Acrocrinus amphora* WACHSMUTH & SPRINGER, 1897; original designation herein.

DIAGNOSIS.—Similar to *Acrocrinus* but differing in its notably taller and narrower radials and primanal, in having only 12 plates in distalmost circlet of intercalaries (five subradial, seven interradial, latter including single subanal), and especially in its robust, long, pendent arms; tegmen formed by extremely numerous small plates without differentiated orals and lacking anal pyramid (Fig. 1,3). *Upper Mississippian (lower Chesteran)*, USA (Alabama).

**AMPHORACROCRINUS AMPHORA**

(Wachsmuth & Springer), Moore & Strimple, n. comb.

*Acrocrinus amphora* WACHSMUTH & SPRINGER, 1897, p. 808, pl. 80, fig. 4-9.—BATHER, 1900, p. 159.—SPRINGER, 1926, p. 45, pl. 9, fig. 8-9, pl. 12, fig. 8-9, pl. 18, fig. 4.

DIAGNOSIS.—Characters of genus.

DESCRIPTION.—Calyx somewhat smaller on average than that of *Acrocrinus shumardi* but generally similar in shape, with height typically 1.5 times greater than width. Specimens illustrated by WACHSMUTH & SPRINGER have calices ranging in height from 17.5 to 32 mm. and maximum width of 12 to 22 mm. The steeply up-flaring basal circlet of a medium-sized calyx has maximum width of 5.5 mm., minimum width at the stem junction of 2 mm. and height of 2 mm. The width of radial plates (av. 3 mm.) is very little greater than their height (av. 2.5 mm.). A very noteworthy attribute of *Amphoracrinus amphora* is its gently arched, many-plated tegmen which lacks differentiated orals and an anal pyramid but shows the anal opening near the CD-interray margin. The very long pendent arms may reach almost as far below the calyx as its full height and the peculiarity of the vertical grooves on sides of the calyx made by their pressure against it is most striking. Diameter of the stem, composed of very low columnals, is normally 2 to 2.5 mm.

ILLUSTRATIONS.—FIG. 1,3. Diagram showing plate arrangement in summit portion of calyx (broad-faceted radials black, distalmost intercalaries gray) showing single subradial intercalary beneath each radial and seven others interradial.—FIG. 2,4-8. Specimens from Monteagle Formation, lower Chesteran, near Huntsville, Madison County, Alabama; all  $\times 2$  (Wachsmuth & Springer, 1897); 4, tegmen, showing slightly differentiated plates adjacent to anal opening (lower part of view) but no anal pyramid or differentiated orals,  $\times 2$ ; 5, C-ray view of lectotype (large primanal and longitudinal series of subanal intercalaries near left edge of calyx),  $\times 2$ ; 6, exceptionally tall and slender calyx with arm

$\times 2$ ; 5-6, side views of calices with arm bases, longitudinal furrows marking impressions of pendant arms,  $\times 2$ ; 7-8, crowns with part of long downhanging arms showing closely spaced long pinnules,  $\times 1.5$ .

9. *Acrocrinus alvestonensis* WRIGHT, ill-preserved holotype, adequate to support recognition of this genus in Europe (Britain), however,  $\times 1.5$ .

bases; 7,8, calices with pendent arms and portion of attached stem, rays not identified.

DISCUSSION.—The most obvious and important differences shown by *Amphoracrinus amphora* as compared to *Acrocrinus shumardi* are its proportionally much taller and nearly quadrate radials, its smaller number of distalmost intercalaries, with only a single such plate beneath each radial, and the pendent nature of its arms. No other acrocrinid genus and species with multiple articular facets occupying the entire distal margin of the radials possesses such relatively tall plates in this circlet, and none of these matches *A. amphora* in having one intercalary plate next beneath every radial. Finally, this species is unique in the pendent attitude of its arms.

TYPES.—Lectotype, U. S. National Museum, no. S1577 (specimen illustrated by WACHSMUTH & SPRINGER, 1897, pl. 80, fig. 6), herein designated, shown in this paper as Fig. 2,5; other specimens here illustrated (also USNM no. S1577) designated as paralectotypes.

OCCURRENCE.—Monteagle Formation (Gasper age), lower Chesteran, near Huntsville, Madison County, Alabama.

### Genus PLATYACROCRINUS Moore & Strimple, n. gen.

TYPE SPECIES.—*Acrocrinus brentwoodensis* MOORE & PLUMMER, 1937 (1938), p. 222; original designation herein.

DIAGNOSIS.—Radials most similar to those of *Acrocrinus* in being very low and wide; primanal distinctive in its subpentagonal shape, narrower than radials, with distal tip projecting slightly above rim of calyx; intercalaries fewer and relatively larger than in other genera of subfamily, most distal circlet containing 15 plates, of which eight are subradial (single ones beneath C and D radials, pairs of plates beneath other radials) and seven interrarial in position, with 3 plates in CD interray (including subanal); tegmen, lower part of calyx (Fig. 1,4). Arms and stem unknown. Lower Pennsylvanian (Morrowan), USA (NW. Arkansas-NE. Oklahoma).

### PLATYACROCRINUS BRENTWOODENSIS (Moore & Plummer), Moore & Strimple, n. comb.

*Acrocrinus brentwoodensis* MOORE & PLUMMER, 1937 (1938), p. 222, pl. 12, fig. 3a-d, text-fig. 3.

DIAGNOSIS.—Characters of genus.

DESCRIPTION.—Only the radial circlet and primanal with subjacent 2 circlets of intercalaries are preserved in the holotype (Fig. 3,1-4). These are quite sufficient, however, to set the species apart from other known acrocrinids. The top part of the calyx is nearly vertical-sided, gently rounded in longitudinal profile, with slight inward slope to summit of the radials. It is 15 mm. in diameter and the incomplete fossil measures 10 mm. in height. Width across the calyx between inner edges of the radials is 10 mm. The radials, with average greatest height of 2.0 mm. and width of 7.0 mm., have almost exactly the proportions of corresponding plates in *Acrocrinus shumardi* (ratio of height to width 28.5 percent in this species and 25 percent in *A. shumardi*). Articular facets of the radials, which reach laterally to the interrarial sutures, are almost imperceptibly concave in lateral profile and subhorizontal from outer to inner margins, with average length of 2.5 mm. along this short axis of the facets. They are most similar to the radial facets of *Planacrocrinus* MOORE & STRIMPLE, n. gen., in displaying a narrow but faint transverse ridge, shallow muscle fields and wide, rather indistinct intermuscular notch. The primanal of *Platyacrocrinus brentwoodensis* is distinctive in its distally rounded or pointed pentagonal outline, with tip rising slightly above the level of the radial facets. Subanal intercalaries occur directly beneath it. Other distalmost intercalaries include 6 in interrarial position and 8 centrally placed beneath radials. The interrarial intercalaries are 1.9 to 4 mm. in height and width; the height and width of subradial intercalaries is 2.8 to 3.0 mm.

Another specimen (SUI 33067), only half as large as the holotype or a little smaller, is a complete calyx with well-defined sutures between nearly all of the plates (Fig. 4). It is vertically compressed and deformed by obliquely directed pressure which has tended to flatten the B-E sides of the calyx. Measurements of greatest diameter (6.5 to 8.5 mm.) and height (6 to 8 mm.) furnish basis for estimating that width and height of the undeformed subglobular calyx to have been approximately 7 mm. The margins of the basal circlet, 2.7 mm. in diameter, slope outward and upward, being visible in side view of the calyx. Near the level of the distalmost intercalaries the calyx sides curve rather abruptly and slope inward to the summit of the radials. The width of the radials is 3 to 4 times their height (A radial 3.8

mm. wide, 1.0 mm. high; *D* radial 2.6 mm. wide, 0.9 mm. high). The articular facets of these plates bear straight transverse ridges reaching nearly or entirely to the interradial sutures; they are very

narrow and sharp-crested. Bordering them on the outer side is a shallow ligament fossa and on the inner side are ill-defined muscle areas separated by a shallow to somewhat narrow inter-

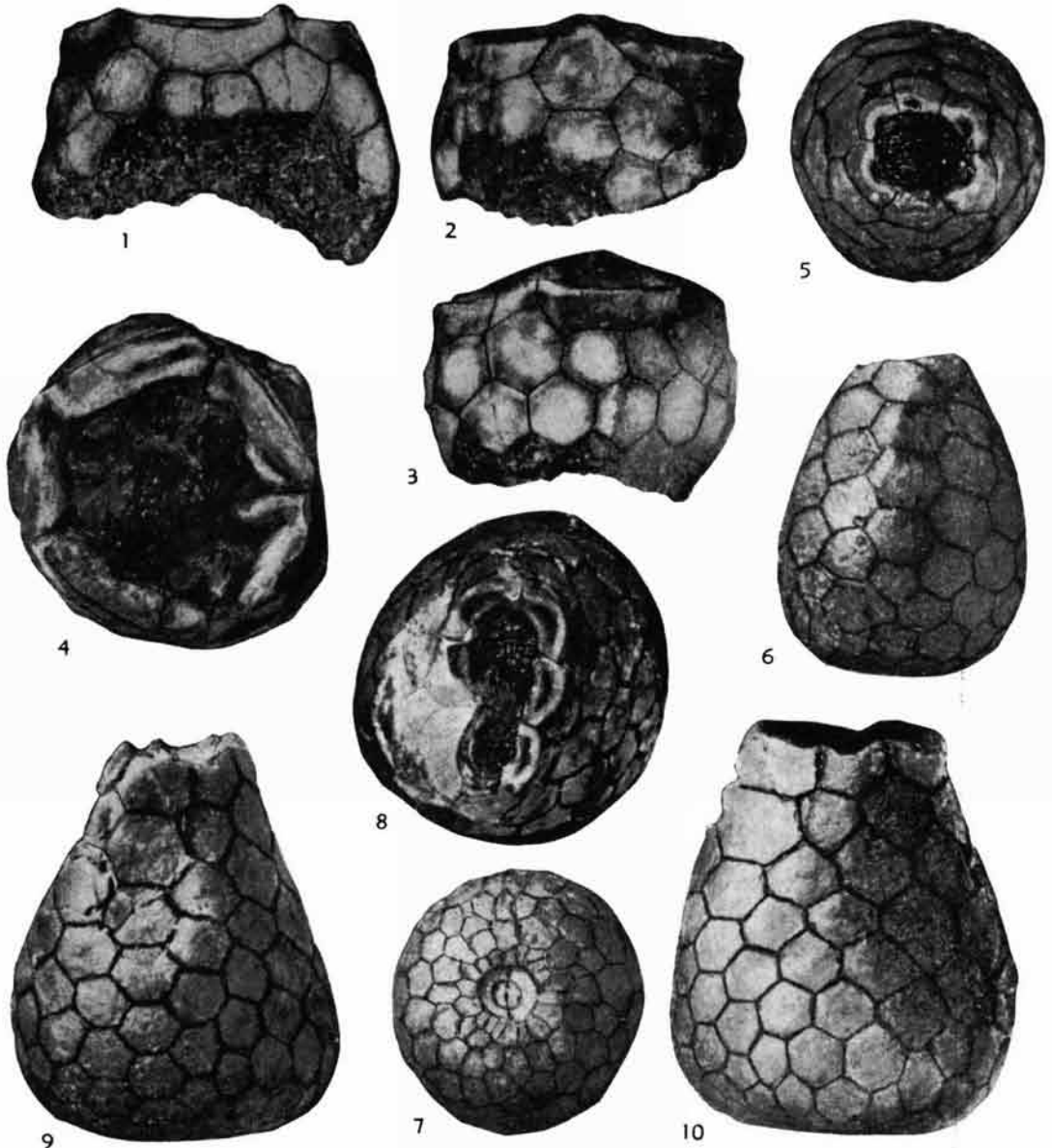


FIG. 3. *Platyacrocrinus* and *Globacrocrinus* MOORE & STRIMPLE, n. gen.

1-4. *Platyacrocrinus brentwoodensis* (MOORE & PLUMMER), MOORE & STRIMPLE, n. comb.; upper part of calyx preserved in incomplete holotype specimen, *B*-ray, *CD*-interray, *A*-ray, and ventral views (primanal centrally placed below in 4), all  $\times 3$  (Moore & Plummer, 1938).

5-10. *Globacrocrinus firum* (MOORE & PLUMMER), MOORE & STRIMPLE, n. comb.; views of calices, all  $\times 3$ .—5-7. Ventral, *CD*-interray, and dorsal views of paratype.—8-10. Ventral, *CD*-interray, and *C*-ray views of holotype (Moore & Plummer, 1938).

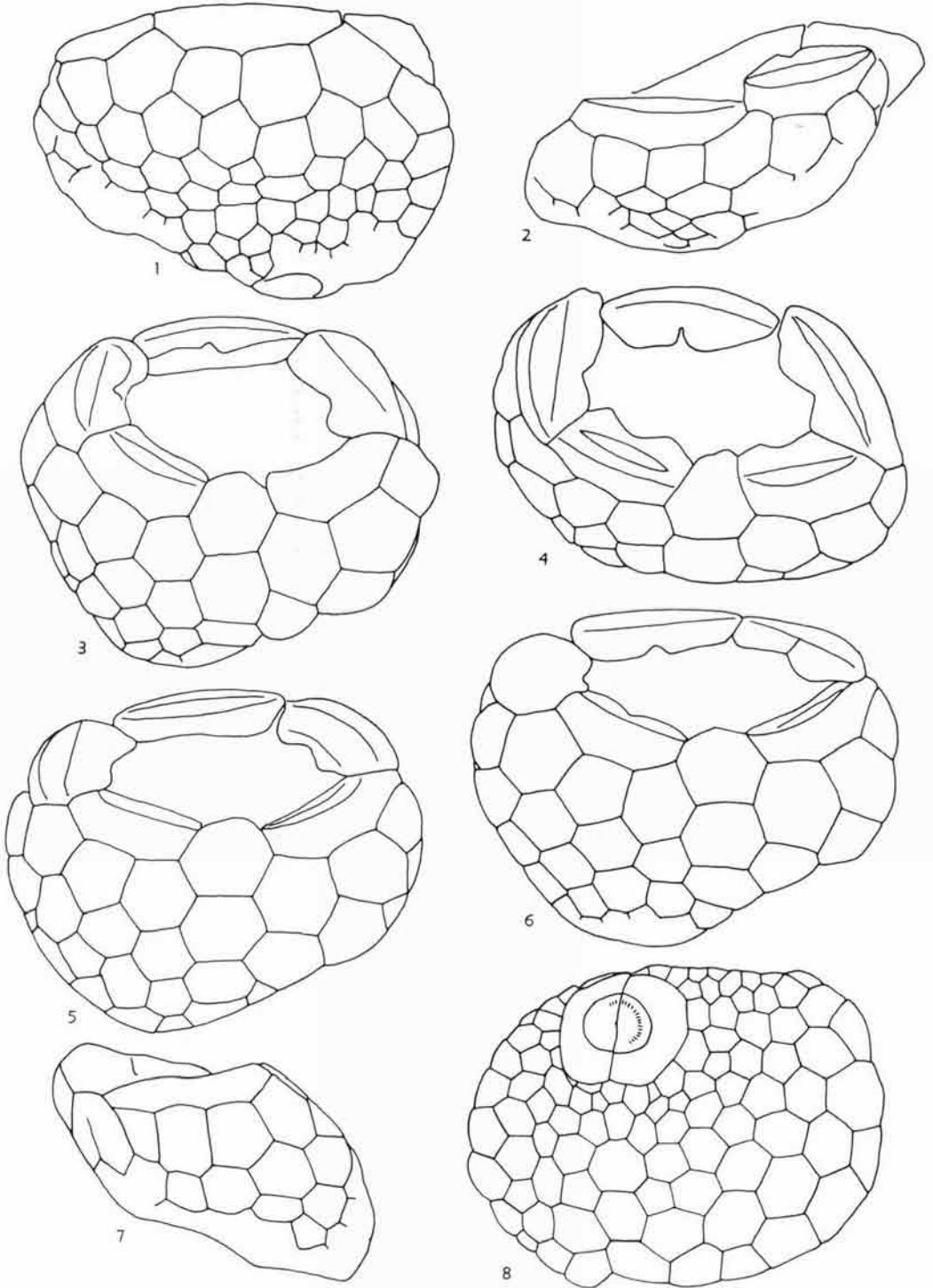


FIG. 4. *Platyacrocrinus brentwoodensis* (MOORE & PLUMMER), MOORE & STRIMPLE, n. comb. (continued on facing page).

muscular notch. The attitude of the facets is subhorizontal. The primanal is relatively shorter than in the holotype and has a subhexagonal outline with rounded distal extremity; it is approxi-

mately the same in width and height (2.0 mm.) as the interrarial intercalaries and very little larger than the subanal intercalary. The intercalaries are arranged in seven or eight ill-defined circlets with

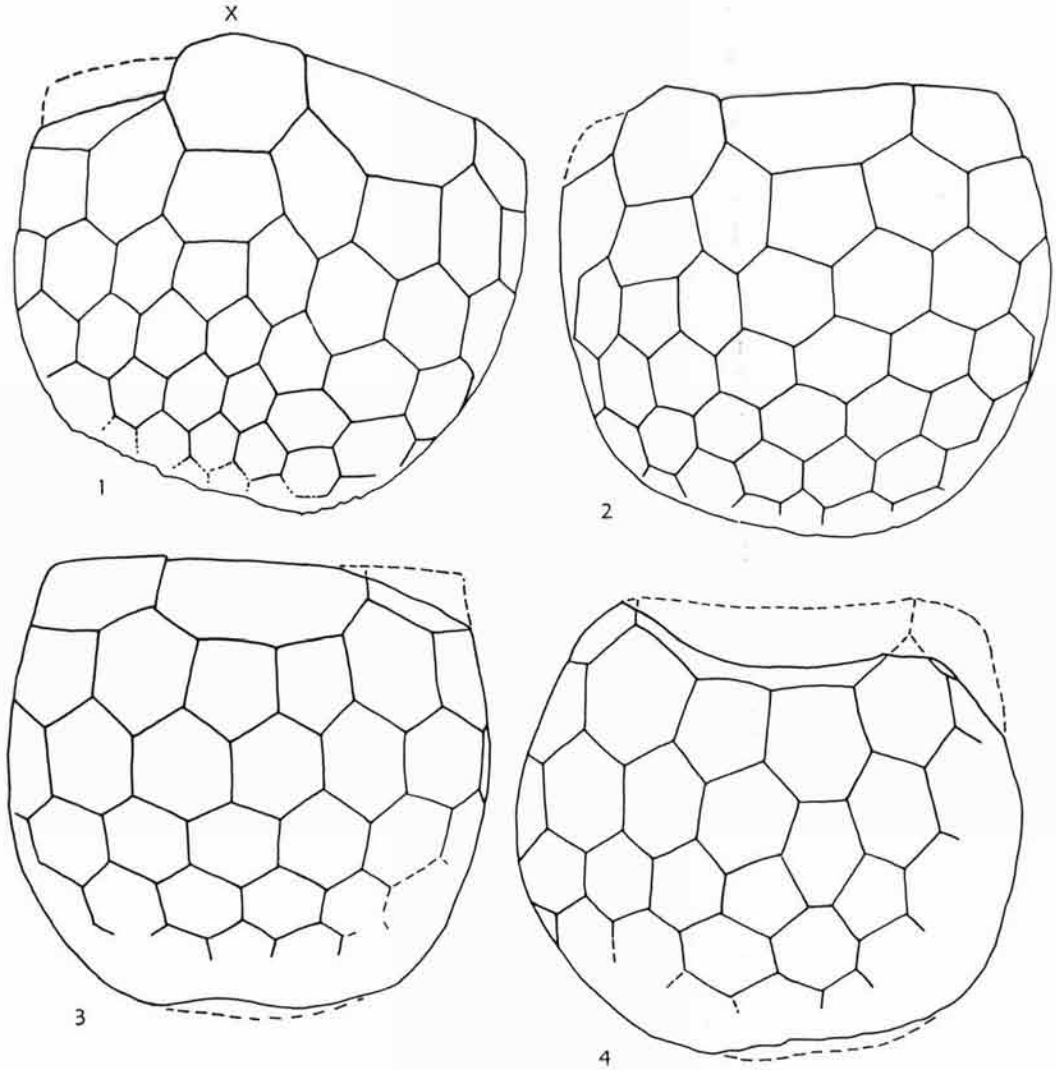


FIG. 5. *Platyacrocrinus brentwoodensis* (MOORE & PLUMMER), MOORE & STRIMPLE, n. comb.

1-4. Camera lucida drawings of nearly complete, undeformed calyx (SUI 33445) from northeastern Okla-

homa, all  $\times 4.5$ : side views of CD interrayer, C, B, and A rays.

1-8. Camera lucida drawings of complete but deformed calyx from northeastern Oklahoma, all  $\times 8$ .—1. A-ray side of calyx showing two distal intercalaries next beneath radial.—2. AB-interray view.—3-6. Oblique views from above of posterior side of calyx showing wide articular facets of radials with

subhorizontally disposed surfaces, relatively small primanal plate with subanal series of intercalaries centrally placed toward viewer.—7. E-ray side of calyx.—8. Oblique view of dorsal side of calyx showing subequal basals surrounded by irregularly arranged small intercalaries.

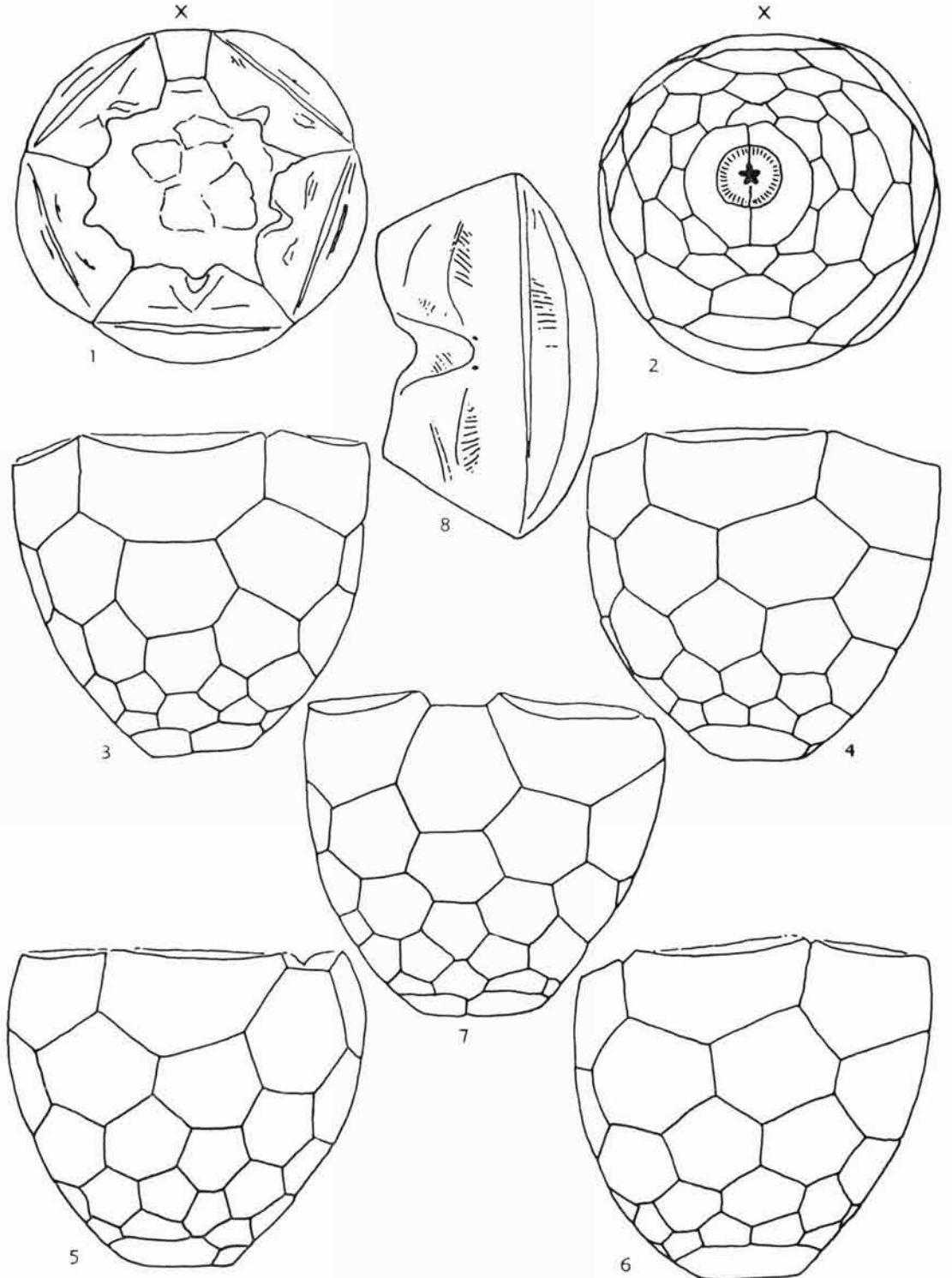


FIG. 6. *Planacrocrinus ambix* MOORE & STRIMPLE, n. gen., n. sp. (continued on facing page).

regularly diminished size of the plates toward the base. The aggregate number of these plates is not less than 100 and may be somewhat more.

A nearly complete undeformed calyx (SUI 33445), also collected from the Brentwood Limestone of northeastern Oklahoma, is subglobular in shape, somewhat abraded at the top and broken at the base, but showing very well most of the calyx sides (Fig. 5). The intercalaries are regularly hexagonal and diminish only moderately in size downward. The basal cirlet and most proximal intercalaries are missing. Outer surfaces of the intercalaries are very gently convex and marked by irregular slight vermiform ridges. Sutures between the intercalaries are distinct and faintly depressed. The calyx is 14 mm. in height and 15 mm. in diameter. The *B* radial is 2.3 mm. wide and 1.0 mm. high; the incomplete *A* radial is 3.5 mm. wide and probable original height is estimated as 1.0 mm. The subhexagonal primanal is wider distally than in the holotype, with dimensions of 4.5 mm. in maximum width and 5.0 mm. in height.

ILLUSTRATIONS.—FIG. 1,4. Diagram showing radial cirlet and primanal with subjacent 15 intercalaries bilaterally symmetrical in arrangement with respect to *A-CD* axis (based on holotype.—FIG. 3,1-4. *B*-ray, *CD*-interray, *A*-ray, and ventral views of holotype,  $\times 2$ , from Brentwood Limestone (Bloyd Formation), Morrowan, near Woolsey, Washington County, Arkansas (Moore & Plummer, 1938).—FIG. 4,1-8. Camera lucida drawings of complete but deformed hypotype (SUI 33067) from vicinity of Choteau (NE SW sec. 1, T. 20 N., R. 18 E.), Mayes County, Oklahoma, all  $\times 8$ ; 1, *A*-ray side of calyx; 2, *AB*-interray view; 3-6, oblique views of post. side of calyx from above; 7, *E*-ray view; 8, oblique view of dorsal side of calyx.—FIG. 5,1-4. Camera lucida drawings of specimen SUI 33445 in side views directed toward *CD* interrayer, *C*, *B*, and *A* rays,  $\times 4.5$  (broken lines indicating restoration).

1-8. Camera lucida drawings of holotype specimen, all  $\times 10$  (except 8, which is  $\times 22$ ).—1-2. Ventral view showing broad-faceted radial-plate cirlet and narrow distal edge of primanal (above) surrounding open tegmental space with remnants of poorly preserved subhorizontal orals, and dorsal view showing equal basals and adjacent proximal intercalaries in fairly regular circlets (primanal plate at top), stem impression with fine short peripheral crenulae and pentalobate lumen,

TYPES.—Holotype, University of Kansas (Museum of Invertebrate Paleontology), no. 45261; paratype, no. 45241; both deposited in U. S. National Museum. Hypotypes, SUI 33067 and 33445.

OCCURRENCE.—Brentwood Limestone (Bloyd Formation), Lower Pennsylvanian (Morrowan), northwestern Arkansas (Washington County) and northeastern Oklahoma (Mayes County).

## Genus PLANACROCRINUS Moore & Strimple, n. gen.

TYPE SPECIES.—*Planacrocrinus ambix* MOORE & STRIMPLE, n. sp.

DIAGNOSIS.—Calyx flat at base and summit, bowl-shaped to subconical with steep nearly straight sides, basals clearly visible in side view; radials wider than high, with straight articular facets occupying full width of plates and extending well inward from outer margin, resembling facets of such inadunate crinoids as *Delocrinus* and *Cromyocrinus* in presence of ligament fossae, transverse ridge, muscle-attachment areas, and intermuscular notch; *C* and *D* radials separated by hexagonal primanal which is widest in lower third and narrowest at summit slightly below level of radial facets or even with them; cirlet of distalmost intercalaries composed of eight plates, only *A* radial having one directly beneath it (Fig. 1,9); tegmen and arms unknown. Lower Pennsylvanian (Morrowan).

### PLANACROCRINUS AMBIX Moore & Strimple, n. sp.

DIAGNOSIS.—Characters of genus.

DESCRIPTION.—The calyx of this species is bowl-shaped, with height subequal to width or distinctly less than greatest width. Upward sloping sides of the lower part of the calyx curve evenly to a vertical attitude at the summit, or in this part they may turn very slightly inward. The

its projections directed interradially.—3-7. Side views of calyx showing even horizontal summit, upflared basals, and circlets of intercalary plates, seen from *A*-, *B*-, *D*-, and *E*-ray sides and *CD*-interrayer side.—8. Articular facet of *A* radial with narrow, straight transverse ridge crossing widest part of facet and separating broad, shallow outer ligament area from nearly flat inner ligament and muscle areas, two minute nerve canal openings near tip of intermuscular notch.

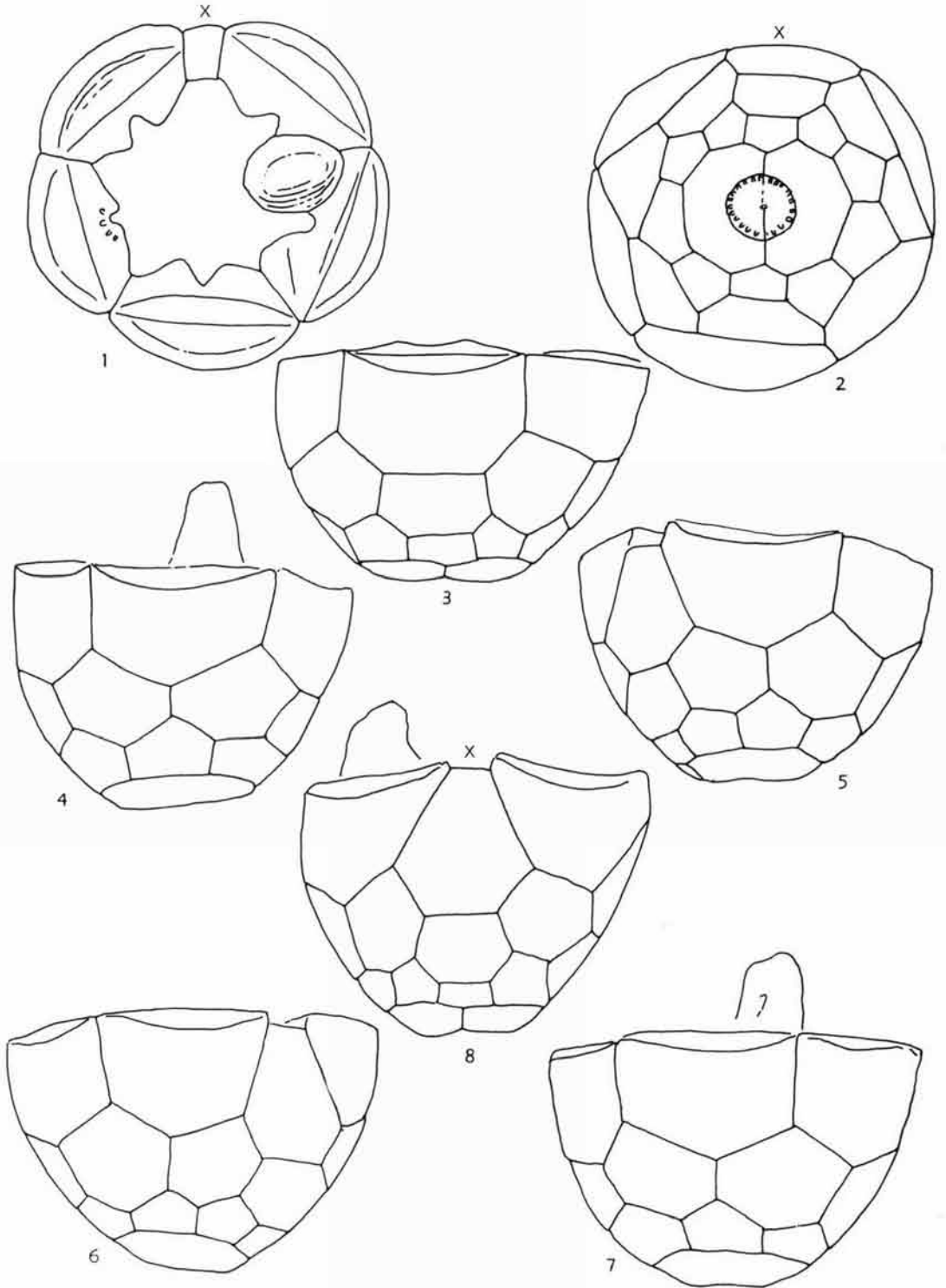


FIG. 7. *Planacrocrinus ambix* MOORE & STRIMPLE, n. gen., n. sp. (continued on facing page).



flat base, with well-marked stem impression, is one-third as wide as the calyx summit, which corresponds to it in being evenly horizontal. Peripheral parts of the basals slope upward and therefore are easily visible in side view, height of the circlet amounting to approximately 0.1 that of the calyx. The radials are distinctly wider than high; all have pentagonal outlines except the *A* radial, which is hexagonal. Their horizontal articular facets are approximately one-half as long measured normal to the transverse ridge, as wide, measured along this ridge. Outside the transverse ridge, extending nearly to the radial margin, is a shallow but distinct ligament fossa and inside are broad muscle areas with ill-defined surface features. The two muscle fields of each facet are separated by a deep, comparatively narrow intermuscular notch, at the base of which on some facets two tiny openings for nerve canals are discernible.

The primanal (*X*) plate is hexagonal in outline, with greatest width slightly below mid-height, this width being equal to total height. Proximal and distal margins of the plate are subequal, the latter not quite reaching to the summit of the adjoining *C* and *D* radials. Directly beneath the primanal are subanal intercalaries, two in small juvenile specimens or three in the holotype, judged to represent an adult. Similarly, two or three subradial intercalaries underlie the hexagonally shaped *A* radial. Distal-most intercalaries additional to the subanal and subradial ones mentioned are all interradian in position. They are comparatively large and all are hexagonal in shape. The total number of intercalaries ranges from approximately 18 in small juveniles to about 40 in adult specimens.

Paired basals, as throughout the family, are separated by an anteroposteriorly directed suture. The peripheral parts of these plates slope gently upward in confluence with curved sides of the calyx and are plainly visible in side views. The stem impression and proximal columnals have diameter of one-half that of the basal circlet or a little less. A narrow band of short, moderately strong crenulae surrounds a broad, smooth areola.

The axial canal and lumen are distinctly stellate in transverse section, with round-tipped extremities of the rays directed interradianly.

The tegmen of *Planacrocricrinus ambix* is unknown, except for the observation of five poorly preserved orals partly displaced from their interradian positions into a central group of the summit of the holotype (Fig. 6,1). One of the paratypes, a small juvenile specimen, retains a single stout tegminal plate which rises steeply upward and inward from the *DE* interradian suture (Fig. 7,1). It corresponds to the *DE* suboral of *P. minutus*, suggesting that the tegmen of *P. ambix* also was characterized by the presence of a rounded pyramid of oral and suboral plates.

Dimensions (in millimeters) of the holotype and paratype, the latter enclosed by parentheses, are as follows. Calyx: H, 5.0 (2.2); D at summit, 5.3 (3.0); D at base (less than that of basal circlet), 1.7 (0.9). *A* radial: H at mid-line, 1.5 (1.1); H at interradian sutures, 1.0 (0.7); W, 2.8 (1.6); L of articular facet from outer to inner margin, 1.5 (0.9). Primanal (*X*) plate: H, 1.9 (1.3); maximum W, 1.9 (1.3). Basal circlet: H, 0.5 (0.3); D, 3.2 (1.5); stem impression, D, 0.6 (0.6).

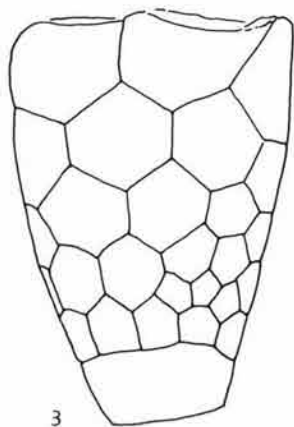
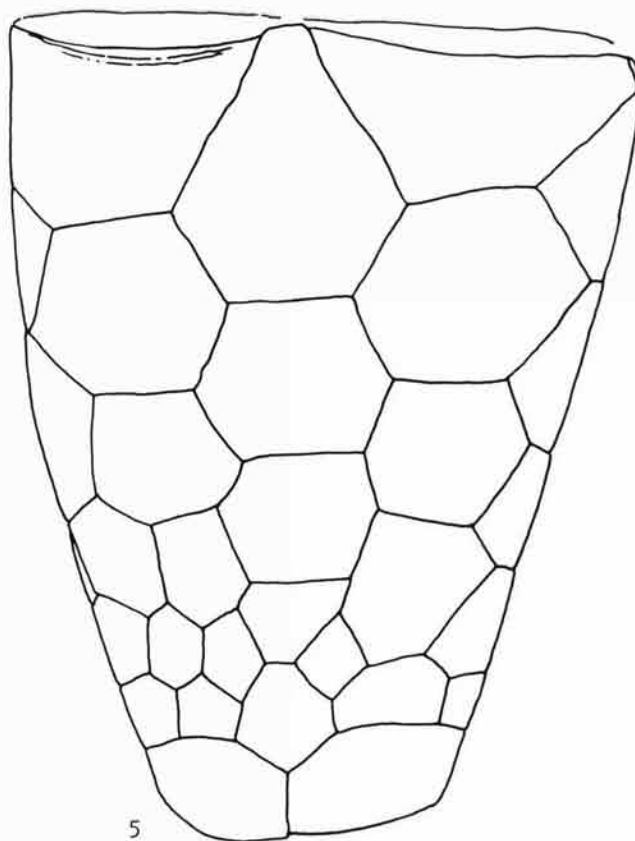
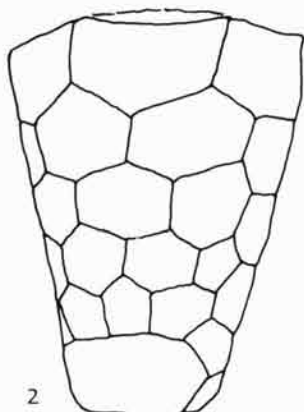
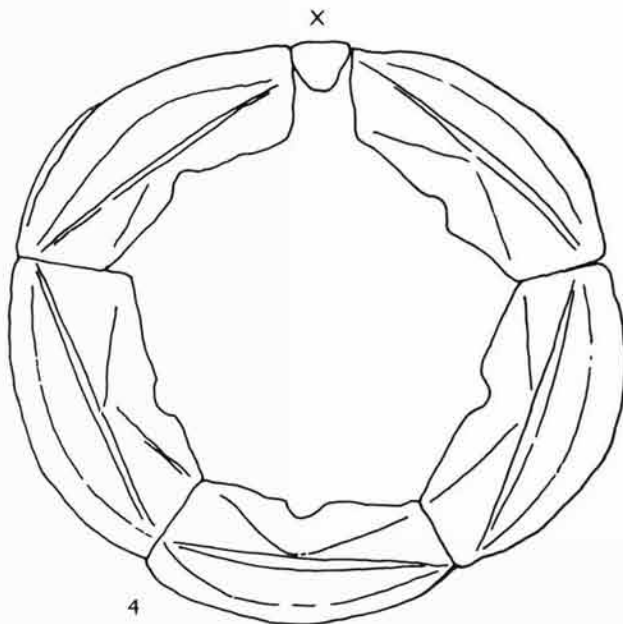
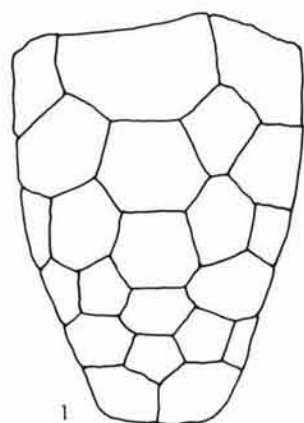
ILLUSTRATIONS.—FIG. 1,9. Diagram showing plate arrangement in summit portion of calyx (radials with wide, straight articular facets black, distal-most intercalaries gray), subradial intercalary only in *A* ray.—FIG. 6,1-8. Camera lucida drawings of holotype (SUI 33105), all  $\times 10$  (except 8, which is  $\times 22$ ); 1-2, ventral and dorsal views; 3-7 *A*-, *B*-, *D*-, *E*-ray, and *CD*-interray views; 8, radial articular facet,  $\times 22$ .—FIG. 7,1-8. Camera lucida drawings of paratype (SUI 33106), all  $\times 18$ ; 1-2, ventral and dorsal views, former showing suboral plate in *DE* interrady; 3-8, *A*-, *B*-, *C*-, *D*-, *E*-ray and *CD*-interrady views (profile of suboral shown in 4, 7, and 8).

TYPES.—Holotype, SUI 33105; paratype, SUI 33106. Collected by ALLEN GRAFFHAM.

OCCURRENCE.—Wapanucka Limestone, Lower Pennsylvanian (Morrowan), Canyon Creek near Fittstown, Pontotoc County, Oklahoma.

1-8. Camera lucida drawings of small paratype specimen, all  $\times 18$ .—1-2. Ventral view (distal extremity of primanal at top) showing single preserved suboral plate projecting strongly upward from *DE* interradian suture, and dorsal view showing basals with greatest width in

direction normal to interbasal suture and illustrating relatively small number of intercalaries arranged in two circlets.—3-8. Side views of calyx looking toward *A*, *B*, *C*, *D*, and *E* rays and *CD* interrady (profile of suboral shown in 4, 7, and 8).



**PLANACROCRINUS CONICUS Moore & Strimple, n. sp.**

DIAGNOSIS.—Similar to *Planacrocrinus ambix* in all essential structural features of calyx, but distinguished by its much greater height in relation to width and its nearly straight, very steeply sloping sides.

DESCRIPTION.—The calyx has the form of a tall truncate cone with summit diameter slightly greater than twice that of the base, the former equaling 75 percent and the latter 60 percent of total calyx height (Fig. 8). Most of the basal circlet is disposed horizontally but its peripheral parts slope steeply upward in line with higher sides of the calyx. The radials correspond in general features to those of *Planacrocrinus ambix*, but the primanal is proportionally taller and much narrower at the summit than in that species, with the tip even or slightly above the *C* and *D* radial articular facets (Fig. 8.5). The intercalaries are as numerous as in adult specimens of *P. ambix*, and like them, show distinct diminution in size toward the basal circlet.

The radial articular facets, disposed in a common horizontal plane, have well-defined narrow transverse ridges, shallow outer ligament fossae, and well-marked muscle areas separated by a shallow intermuscular notch. No parts of the tegmen are preserved.

Dimensions (in millimeters) of the calyx and some of its component parts are as follows. Calyx: D summit, 2.8; D at base (less than that of the basal circlet), 1.6; H, 5.2. *A* radial: H at midline, 1.2; H at interradial sutures, 0.8; W, 1.6; L of articular facet, 0.8. Primanal (*X*) plate: H, 1.8; maximum W, 1.5. Basal circlet: D, 2.0; H, 0.9; stem impression, D, 0.8.

ILLUSTRATIONS.—FIG. 8.1-5. Camera lucida drawings of the holotype (SUI 33107); 1-3, *A*-, *B*-, and *D*-ray views of calyx,  $\times 10$ ; 4-5, *CD*-inter-ray and ventral views of calyx, latter with *A* ray central below,  $\times 22$ .

DISCUSSION.—Diminutive size and very steep straight sides are obvious distinguishing features of this species. The holotype is judged to be an

adult individual for it has a somewhat larger complement of intercalary plates than adult *Planacrocrinus ambix*. Four subanal and four subradial intercalaries in the *A* ray are observed instead of the three of *P. ambix*.

TYPE.—Holotype SUI 33107 (only known representative of the species). Collected by R. C. MOORE.

OCCURRENCE.—Brentwood Limestone (Bloyd Formation), Lower Pennsylvanian (Morrowan), at Greenleaf Lake, north of Muskogee, Oklahoma.

**PLANACROCRINUS MINUTUS Moore & Strimple, n. sp.**

DIAGNOSIS.—Calyx proportionally taller than in *Planacrocrinus ambix* and with far fewer plates as well as steeply upflaring borders of basal circlet notably taller; tegmen marked by prominent oral pyramid composed of oral plates at summit, supported by suborals which rise from interradial sutures. Arms and stem unknown.

DESCRIPTION.—This species is based on a single complete calyx which is slightly compressed anteroposteriorly. It is notably smaller than *Planacrocrinus ambix* and *P. conicus*, with profile in side view intermediate between these two species (Fig. 9.2-10). Diameter of the radial circlet is nearly half of the calyx height and the basal circlet one-fourth of it, leaving room between them for only a double row of intercalaries, large ones located distally and small ones proximally. The primanal (*X*) is a lozenge-shaped plate with greatest width slightly below mid-height. Its summit, slightly below the level of the radial facets, is distinctly narrower than the base. It is underlain by a single subanal intercalary plate, instead of the two circlets of intercalaries beneath radials.

The oral pyramid has steeply sloping sides and pointed to rounded summit (Fig. 9.2-10). The lower half of its height is composed of five suboral plates and the upper part by five closely adjoined orals, the posterior one of which is slightly larger than others. The base of the oral arch, formed by

FIG. 8. *Planacrocrinus conicus* MOORE & STRIMPLE, n. gen., n. sp. (on facing page).

1-3. Camera lucida drawings of holotype from *A*- and *B*-ray and *DE*-inter-ray sides showing nearly horizontal summit with diameter little more than twice that of flatly truncate base, peripheral parts of basals very

steeply upflared in line with calyx sides,  $\times 10$ .—4-5. Ventral view showing broad radial articular facets and distal edge of primanal (at top), and *CD*-inter-ray view of calyx,  $\times 22$ .

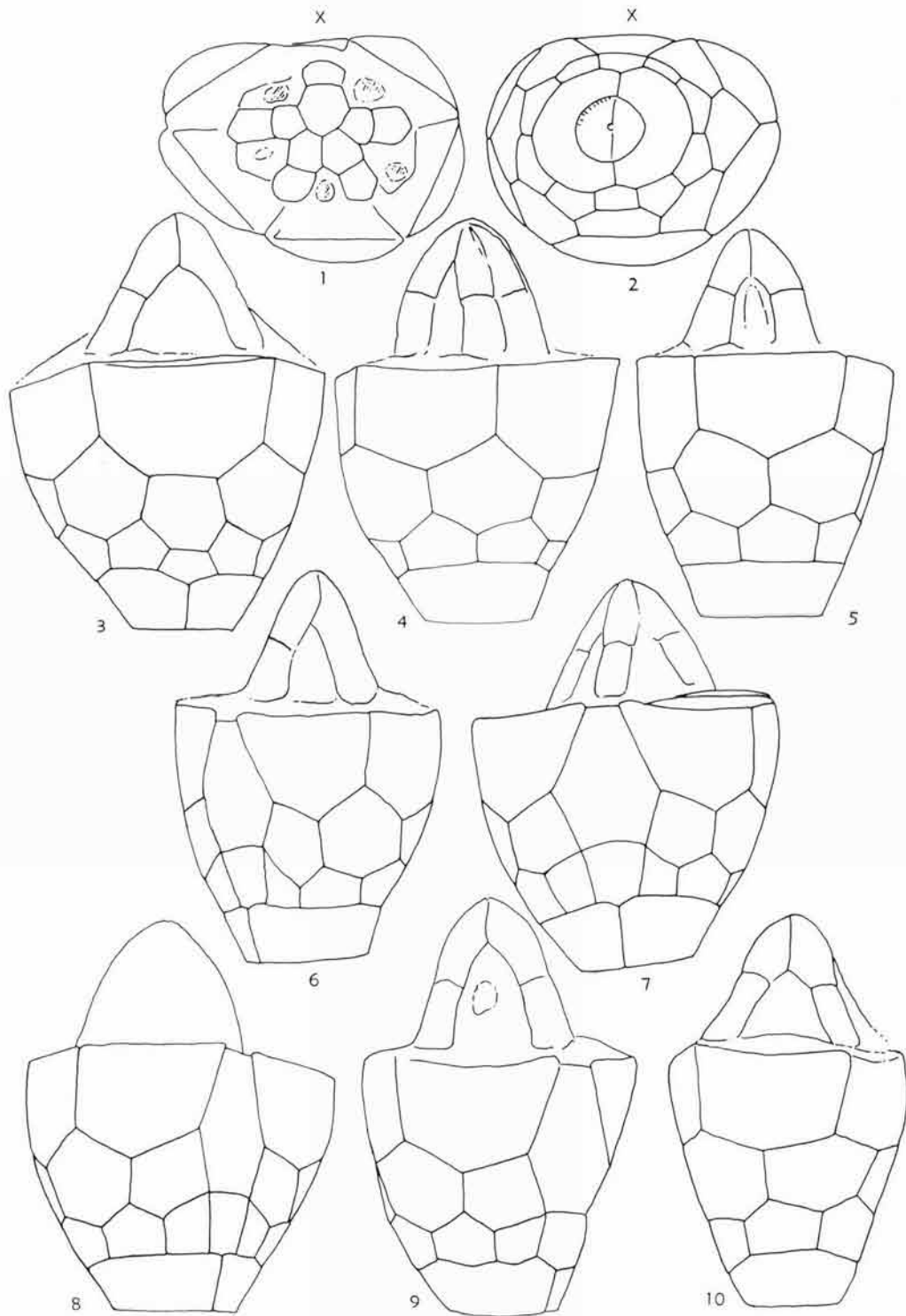


FIG. 9. *Planacrocrinus minutus* MOORE & STRIMPLE, n. gen., n. sp. (continued on facing page).

proximal extremities of the suborals, is well inside the outer edges of the horizontal radial articular facets. These have narrow straight transverse ridges and on the inner side shallow intermuscular notches.

Dimensions of the holotype (in mm.) are as follows. Calyx: H, 2.3; D (summit), 2.0 and 2.6, mean 2.3; D (base), 1.0 and 1.4, mean 1.2. *B* basal circlet: H, 0.5; D (stem impression), 0.6. Oral pyramid: H, 1.1; W (at base), 1.5. *A* radial: H (mid-line), 0.9; H (at interrarial suture), 0.7; W (summit), 1.7; W (base), 0.7. Primanal (*X*) plate: H, 1.2; W, 1.0.

ILLUSTRATIONS.—FIG. 9, 1-10. Camera lucida drawings of holotype (SUI 32482), only known specimen, all  $\times 18$ ; 1-2, ventral and dorsal views of calyx, former showing centrally grouped orals and supporting suborals; 3-10, *A*-, *AB*-, *B*-, *C*-, *CD*-, oblique *D*-, *D*-, and *E*-ray and interray views.

TYPE.—Holotype, SUI 32482. Collected by ALLEN GRAFFHAM.

OCCURRENCE.—Brentwood Limestone (Bloyd Formation), at Greenleaf Lake, north of Muskogee, Oklahoma.

### Subfamily GLOBACROCRININAE

#### Moore & Strimple, n. subfam.

Distinguished from Acrocrininae by narrow, moderately to strongly arcuate radial articular facets; basals visible or not visible from side; distal-most ring of intercalaries composed of six to 12 plates, of which seven are located interradially in all but one genus (*Protacrocrinus*), subradial intercalaries ranging from none to five, some genera with longitudinal series of superposed intercalaries beneath one to three radials in addition to primanal series present in all; tegmen with distinct orals recognized in some genera, posterior one largest, and commonly showing low anal pyramid near *CD* border. *Upper Mississippian* (*Chesteran*)-*Upper Pennsylvanian* (*Missourian*), *Middle Carboniferous* (*Moscovian*).

DESCRIPTION.—Chief characteristics of species grouped in the Globacrocrininae are found in the generally diminutive to very small size of the

calyx and greatly reduced number of intercalaries in comparison to the Acrocrininae. Maximum calyx height in any species is only 18 mm. and calyx width 15 mm. From these measurements height and width of the calyx ranges down to 5 mm. The number of intercalaries is largest in some species of *Globacrocrinus* (approximately 175), which is barely one-third or less of the intercalary plates in calices of *Amphoracrocrinus* and *Acrocrinus*. The narrow and more or less strongly arcuate facets at the summits of radial plates is another diagnostic feature of this subfamily. In stratigraphic span and in being represented on both sides of the Atlantic, the Globacrocrininae match distribution of the family.

### Genus GLOBACROCRINUS Moore & Strimple, n. gen.

TYPE SPECIES.—*Acrocrinus pirum* MOORE & PLUMMER, 1937 (1938), p. 218; original designation herein.

DIAGNOSIS.—Calyx pear-shaped to globose, basals not visible from side; small to very diminutive radials with height and width subequal, little larger than distal-most intercalaries, which form circlet of 8 plates with subradial one confined to *A* ray, others (including subanal) interrarial in position, longitudinal series of intercalaries beneath *A* radial and primanal; tegmen with orals and anal pyramid. Stem slightly heteromorphic, at least next to calyx. Arms unknown. *Lower Pennsylvanian* (*Morrowan*) to *Middle Pennsylvanian* (*Desmoinesian*).

DESCRIPTION.—This genus is the most robust in size of the calyx and largest in number of intercalaries of any unit included in the subfamily. Average height of calyx in different species ranges from 7.5 to 18 mm. and width from 6 to 15 mm.; for the whole genus these dimensions have means of 10 and 9 mm., respectively. The horizontal basals may be flush with the evenly rounded, essentially flat bottom part of the calyx or located in a shallow depression. In most specimens of *Globacrocrinus*, the tegmen is not preserved, but in some forms 5 prominent, subhorizontally dis-

1-10. Camera lucida drawings of holotype calyx, all  $\times 18$ .

—1-2. Ventral and dorsal views, former showing exceptionally broad flat articular facets of radials surmounted by arch of five suboral and five oral plates (posterior oral largest and oriented upward).—3-10.

Side views of calyx looking toward *A* ray, *AB* interray, *B* and *C* rays, *CD* interray (hexagonal primanal facing viewer), two *D* and *E* ray sides, all showing strongly elevated oral-suboral arch (only profile of it in 8).

posed orals are seen, the posterior one trapezoidal in outline and double the size of others. Also, a very low anal pyramid may be present just above and inside the primanal. The nature of arms and stem in *Globacrocrinus* is unknown.

DISCUSSION.—Compared with other genera of the subfamily, *Globacrocrinus* is not only distinguished by characteristics mentioned in the preceding description but by the number and ar-

range of its distalmost intercalaries. Only one of these plates occurs directly beneath a radial (*A* ray) in *Globacrocrinus*, whereas *Protacrocrinus* and *Dinacrocrinus* have 5 such plates, *Metacrocrinus* 4, and *Springeracrocrinus* none. The most distal circlet of intercalaries consists of 12 plates in *Dinacrocrinus*, 11 in *Metacrocrinus*, 8 in *Globacrocrinus*, and only 7 in *Springeracrocrinus*.

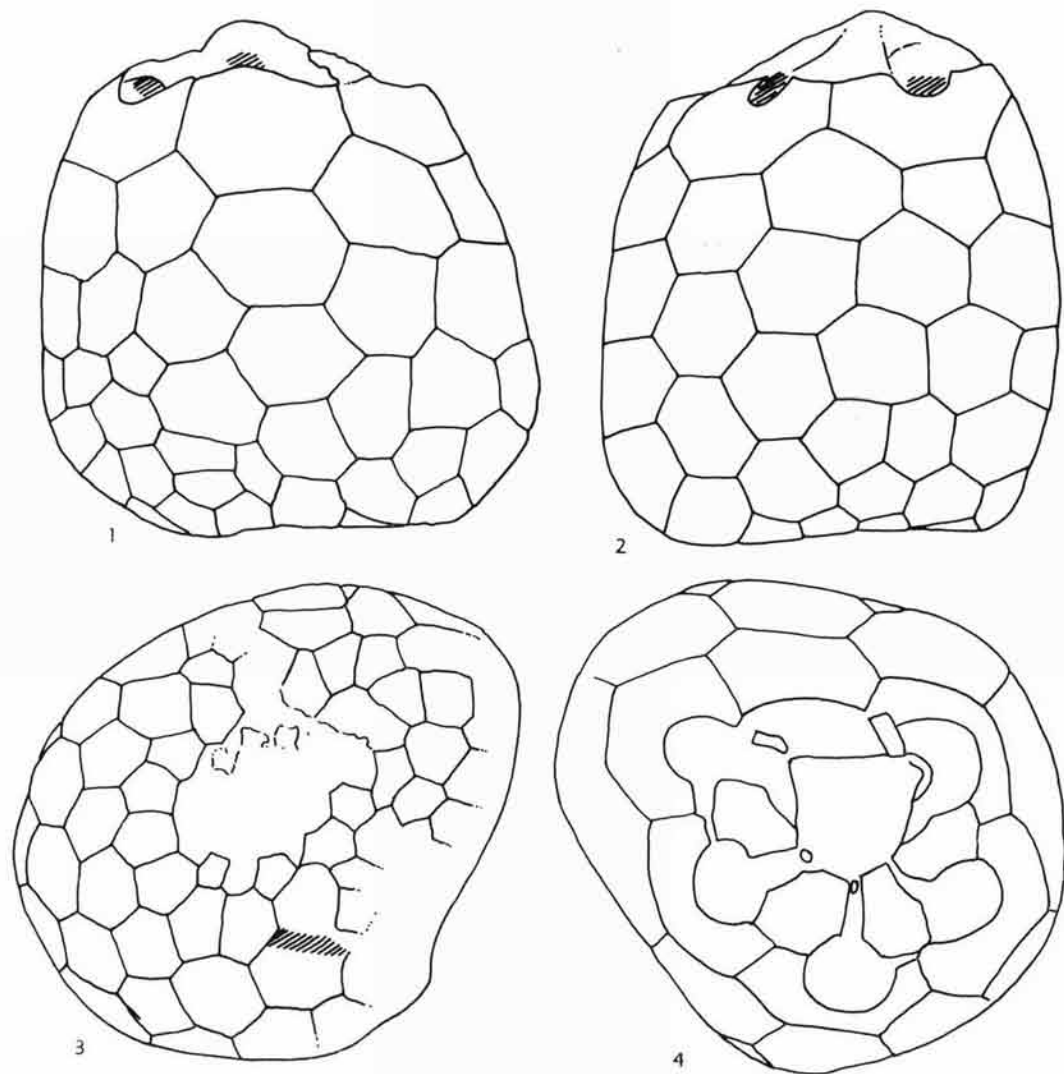


FIG. 10. *Globacrocrinus glomus* MOORE & STRIMPLE, n. gen., n. sp.

1-4. Camera lucida drawings of holotype calyx, all  $\times 10$ .  
—1-2. Side views looking toward *CD* and *AB* inter-rays showing subquadrate outline of calyx with broadly truncate, slightly hollowed base and nearly flat summit.

—3-4. Dorsal and ventral views, basals not preserved five orals at summit sloping upward very gently toward center, large posterior oral oriented toward top.

**GLOBACROCRINUS PIRUM (Moore & Plummer), Moore & Strimple, n. comb.**

*Acrocrinus pirum* MOORE & PLUMMER, 1937 (1938), p. 218, fig. 1, 2g, pl. 12, fig. 1a-d.

DIAGNOSIS.—Calyx small, pear-shaped, with greatest diameter at about one-third of height

above flat to slightly concave base, sides sloping steeply and evenly upward-inward toward summit; plates smooth, not convex, their surface evenly confluent with adjoining plates so as to produce regular contour of calyx sides and base; sutures between plates distinct but not impressed, their

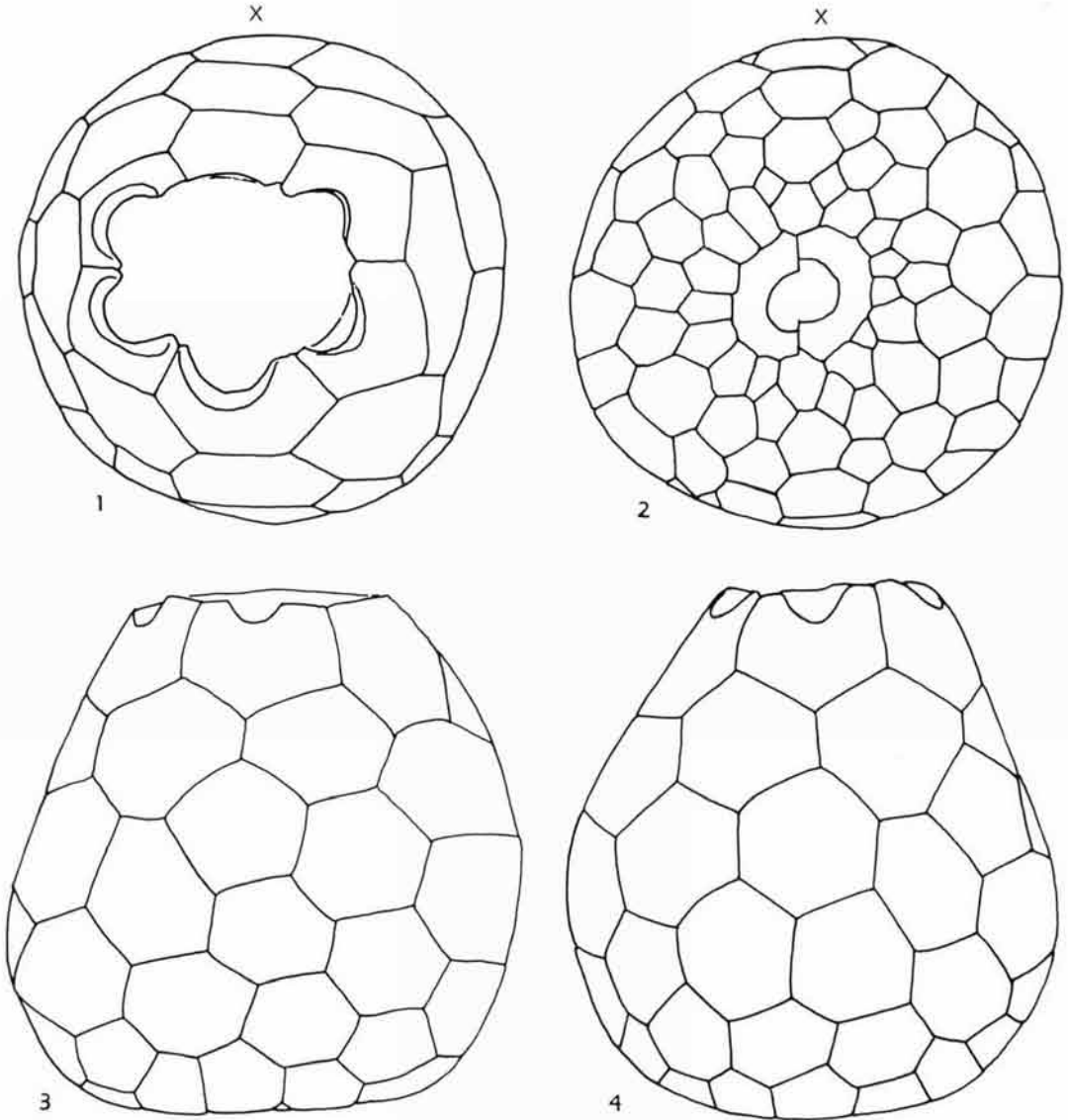


FIG. 11. *Globacrocrinus rotundus* MOORE & STRIMPLE, n. gen., n. sp.

1-4. Camera lucida drawings of holotype calyx, all  $\times 9$ .  
 —1-2. Ventral view showing broadly arcuate radial articular facets slightly less than equal to distal width of radials (primanal directed toward top), and dorsal

side of calyx, basals relatively small.—3-4. Side views looking toward *D* and *E* rays, outline of calyx rounded pear-shaped, intercalaries of sides moderately large and nearly even, in contrast to small plates of calyx bottom.

components and arrangement in accordance with characters of genus.

DESCRIPTION.—The nearly straight sides of the calyx converge toward the relatively narrow summit. The height and greatest width of the holotype are 18 and 15.5 mm., respectively, and in a paratype 14.5 and 11.5 mm. Across the summit

of the radial cirlet, diameter of the calyx is approximately 7 mm. (holotype somewhat deformed in this part) and 5.5 mm. (small but undeformed paratype). The diminutive basal cirlet is 2.5 mm. in both specimens. The hexagonal primanal is readily distinguished from all radials by its even distal margin and lack of an arcuate facet.

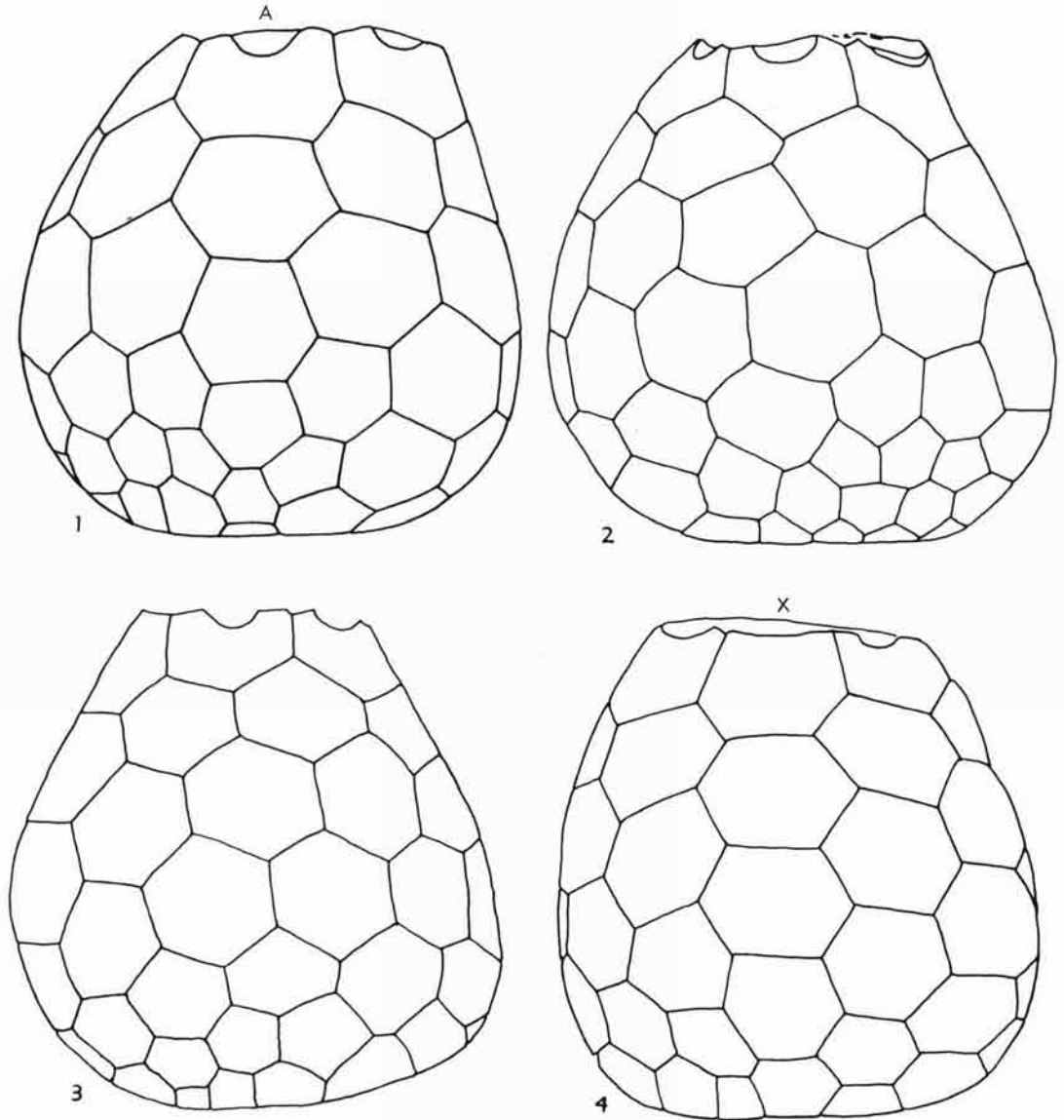


FIG. 12. *Globacrocirinus rotundus* MOORE & STRIMPLE, n. gen., n. sp.

1-4. Camera lucida drawings of holotype calyx, all  $\times 9$ .  
—1-3. Side views looking toward A, B, and C rays.—4. Side view looking toward CD interray,

primanal with longitudinal series of subanal intercalaries reaching to base of calyx.



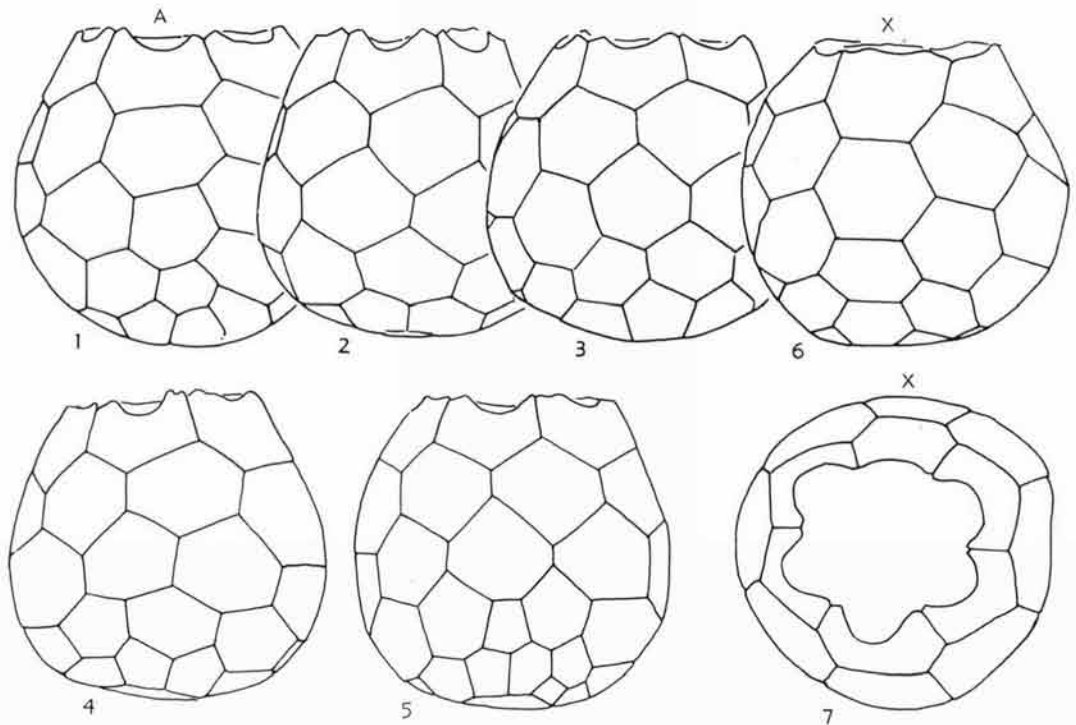


FIG. 13. *Globacrocrinus rotundus* MOORE & STRIMPLE, n. gen., n. sp.

1-6. Camera lucida drawings of medium-sized paratype (OU 6441), presumably a young adult, all  $\times 9$ ; seen

from A-, B-, C-, D-, and E-ray and CD-interray sides. 7. Same in ventral view, primanal above,  $\times 9$ .

It is approximately equal to the radials and distal-most intercalaries in size, and like the radials, is wider than high. The intercalary plates are arranged in nine or ten ill-defined rows girdling the calyx and by count number 160 to 170, including the irregular small plates surrounding the paired basals. The basal circling is 2.5 mm. in diameter.

ILLUSTRATIONS.—FIG. 1,5. Diagram showing plate arrangement of calyx (radials black, distal-most intercalaries gray) (Moore & Plummer, 1938, mod.).—FIG. 3,5-10. Views of calices, all  $\times 3$ ; 5-7, ventral, CD-interray, and dorsal views of paratype; 8-10, ventral, CD-interray, and C-ray views of holotype (Moore & Plummer, 1938).

DISCUSSION.—This species resembles *Globacrocrinus rotundus* but is two or three times larger and has straighter upper sides of the calyx which converge more strongly toward the summit. Also, its intercalary plates are distinctly greater in number.

TYPES.—Holotype, KU45192, from loc. 4519; paratype, KU45212, from loc. 4521; both deposited on indefinite loan in U. S. Natl. Museum.

OCCURRENCE.—Brentwood Limestone (Bloyd Formation), Lower Pennsylvanian (Morrowan), northeastern Oklahoma. Loc. 4519, Keough quarry, sec. 36, T. 16 N., R. 19 E., about 2 miles north of Fort Gibson, Muskogee County; holotype collected by C. L. FOSTER. Loc. 4521, on

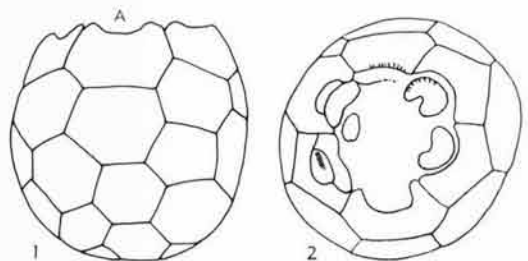


FIG. 14. *Globacrocrinus rotundus* MOORE & STRIMPLE, n. gen., n. sp.

1-2. Camera lucida drawings of paratype (OU 6443), interpreted to be a juvenile specimen with relatively few intercalary plates, both  $\times 7.5$ ; calyx seen from A-ray side and in ventral view, latter with remnant primabrachs in B, C, and D rays, primanal in upper position.

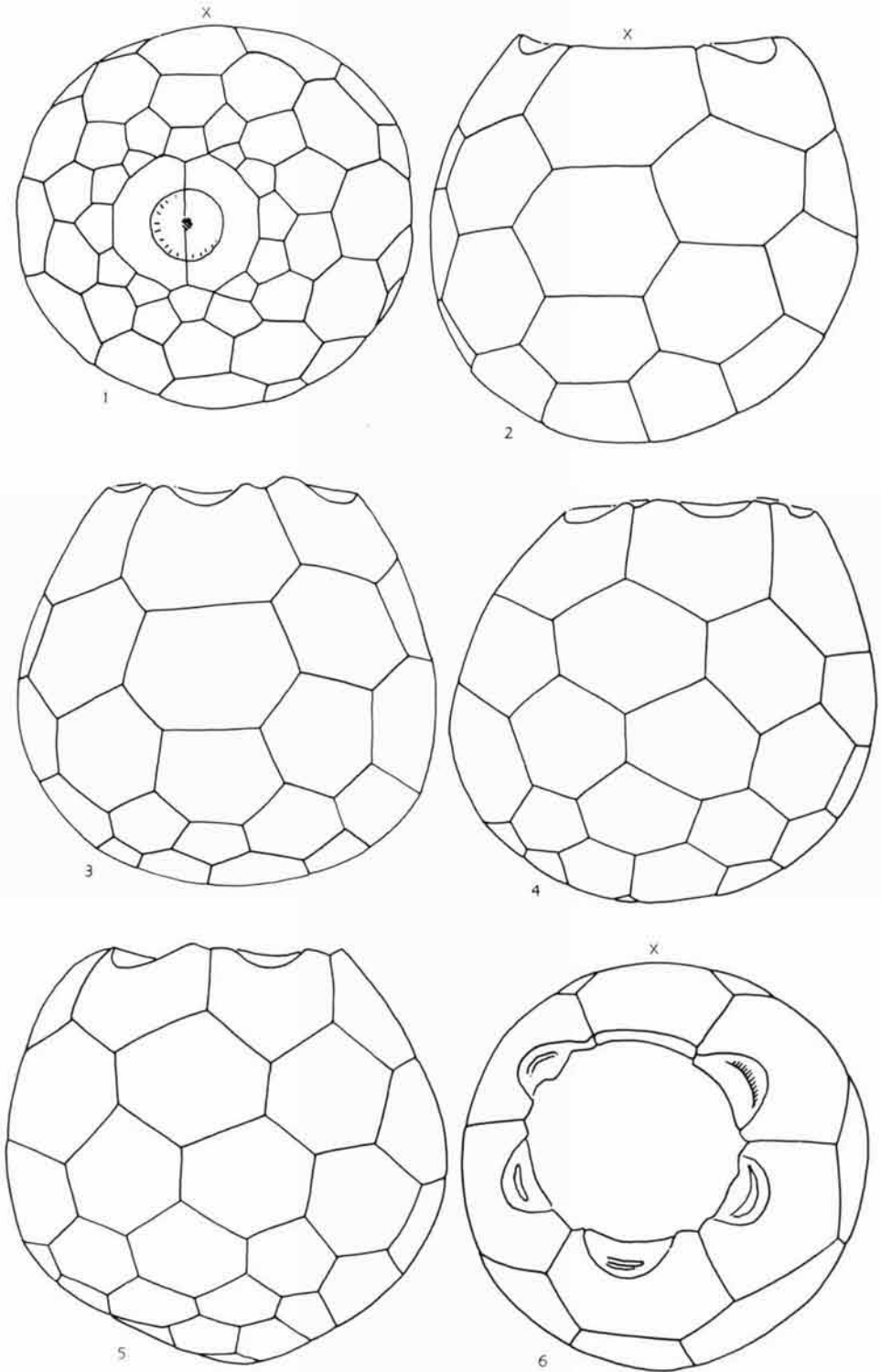


FIG. 15. *Globacrocrinus rotundus* MOORE & STRIMPLE, n. gen., n. sp. (continued on facing page).

Braggs Mountain, about 3 miles southeast of Fort Gibson; paratype collected by R. C. MOORE.

**GLOBACROCRINUS GLOMUS Moore & Strimple, n. sp.**

DIAGNOSIS.—Differs from *Globacrocrinus pirum* in globose shape of calyx, smaller size, and fewer intercalaries.

DESCRIPTION.—The holotype, which is the only yet-collected specimen, is a slightly deformed calyx with steep gently rounded sides and truncate base and summit. It is complete, except for the missing basals and a few adjoining small intercalaries. The base is almost imperceptibly concave. Height and greatest width of the calyx are subequal, amounting to 6.5 mm. Width measured at the proximal margin of the radial circlet is 5.5 mm. and at its distal margin 4.5 mm. Height and width of individual radials and of the primal are 1.5 and 2.5 mm., respectively. Space at the summit of the calyx between the radials is nearly filled by five subhorizontal oral plates, the posterior one 1.9 mm. wide at its straight primal-facing base and 1.7 mm. in height. The other orals average 1.2 mm. in height and 0.9 mm. in greatest width. Intercalaries in series beneath the *A* radial and primal number 7 or 8. As in *Globacrocrinus pirum*, intercalaries are not arranged in well-defined circlets.

ILLUSTRATIONS.—FIG. 10, 1-4. Camera lucida drawings of calyx (holotype) in *CD*- and *AB*-interray, basal, and summit views,  $\times 10$ .

DISCUSSION.—The contour of the calyx of *Globacrocrinus glomus*, especially its rounded quadrate outline in side view, with relatively wide flat base and truncate summit, most closely resembles *Dinacrocrinus expansus* (STRIMPLE) and *D. wortheni* (WACHSMUTH), but these crinoids are readily distinguished by their 12 distalmost intercalary plates, four more than in *Globacrocrinus*, and of course a different arrangement of these plates. Specimens of *G. rotundus* are more rounded at base of the calyx and are narrower at the summit.

TYPE.—Holotype, SUI 32931. Collected by H. L. STRIMPLE.

OCCURRENCE.—Oologah Limestone, Middle Pennsylvanian (Desmoinesian), east of Tulsa, Oklahoma.

**GLOBACROCRINUS ROTUNDUS Moore & Strimple, n. sp.**

DIAGNOSIS.—Essentially with morphological features of *Globacrocrinus glomus* but lower part of calyx very evenly rounded, instead of concavely truncate, upper part also well rounded or with nearly straight sides converging inward to narrow radial circlet; radial articular facets proportionally wider and shallower than in *G. glomus*.

DESCRIPTION.—This species is based on five perfect calices which range in height from 3.9 to 7.8 mm. and in greatest width from 4.0 to 7.5 mm.; average height for all specimens is 5.4 mm. and greatest width 5.3 mm. Width at the proximal margin of the radial-primal circlet averages 4.9 mm. and at the distal edge 3.5 mm. The aggregate number of intercalaries ranges from approximately 70 in small specimens to 120 or more in large ones. Diameter of the basal circlet in the moderately large holotype is 2.0 mm. and that of the stem impression 1.0 mm. In this specimen average height and width of radial plates are 2.3 and 2.7 mm., respectively. No attached proximal columnals of the stem are seen and none of the calices is associated with arms, although one paratype (OU 6643) has stout primibrachs *I* just inside the arcuate radial facets. Some of these brachials show very fine short crenulae along their convex outward-facing edges. Oral plates are not found at the summit of any specimen, although doubtless they once were present.

ILLUSTRATIONS.—FIG. 11, 1-4. Camera lucida drawings of holotype in ventral (*CD* interrayer above), dorsal (also *CD* interrayer above), *D*- and *E*-ray views, all  $\times 9$ .—FIG. 12, 1-4. Camera lucida drawings of holotype (OU 6440) in *A*-, *B*-, *C*-ray and *CD*-interrayer views, all  $\times 9$ .—FIG. 13, 1-7. Camera lucida drawings of paratype (OU 6441) in *A*-, *B*-, *C*-, *D*-, *E*-ray, *CD*-interrayer, and ventral views (*CD* interrayer above), all  $\times 9$ .—FIG. 14, 1-2. Camera lucida drawings of paratype (OU 6443) in *A*-ray and ventral views,  $\times 7.5$ .—FIG. 15, 1-6. Camera lucida drawings of paratype (SUI

1-6. Camera lucida drawings of paratype (SUI 32939) with unusually even-sized intercalaries in fairly well-defined circlets, all  $\times 17$ ; seen from base of calyx

(*CD* interrayer above), from *CD*-interrayer, *A*- and *B*-ray, *DE*-interrayer, and ventral sides (primal above).

32939) with unusually even-sized intercalaries in upper part of calyx, in dorsal (*CD* interray above), *CD*-interray, *A*-, *B*-ray, *DE*-interray, and ventral (*CD* interray above) views, all  $\times 17$ .

DISCUSSION.—At least three of the paratypes of *Globacrocrinus rotundus* are small specimens, with mean height of the calyx measured as 4.2 mm. and mean width as 4.4 mm. These are judged to be juvenile forms, not only because of their diminutive size but because they possess only half as many intercalaries (approximately 40) as seen in the holotype and a nearly as large paratype, which have 80 to 85 intercalary plates. The main distinguishing characteristic of the species is the globose form of the calyx. The holotype is slightly pear-shaped, with gently curved upper sides which slope inward to the relatively narrow summit. Although this suggests *G. pirum*, the calyx of *G. rotundus* is proportionally wider and lower. Also, the paratype specimens are sub-spherical in shape.

TYPES.—Holotype (OU 6440), paratypes (OU 6441-6443, SUI 32939), all from Wapanucka Limestone near Fittstown, Oklahoma. Collected by ALLEN GRAFFHAM (except SUI 32939 by R. ALEXANDER).

OCCURRENCE.—Wapanucka Limestone, Lower Pennsylvanian (Morrowan), Canyon Creek near Fittstown, Pontotoc County, Oklahoma.

### Genus CAUCACROCRINUS Moore & Strimple, n. gen.

TYPE SPECIES.—*Caucacrocrinus urnula* MOORE & STRIMPLE, n. sp.

DIAGNOSIS.—Diminutive calyx urn-shaped or lanceolate in outline, pointed at base, basals distinctly upflaring, visible from side; distalmost intercalaries normally forming circle of 11 plates, with subradial ones directly beneath *A*, *C*, *D*, and *E* radials or exceptionally with subradials in all rays; tegmen with low to moderately prominent anal pyramid at its posterior margin adjoining primanal (*X*) plate, and accompanying this on its anterior side five subhorizontally disposed orals at level of the radial articular facets, posterior oral distinctly larger than others; remainder of tegmen covered by minute plates; only known parts of arms consist of primibrachs which have deep ambulacral embayment on inner side, are strongly rounded externally, and have distal artic-

ular facets parallel to proximal ones, thus indicating uniserial proximal arm structure, as in other acrocrinids. Stem transversely circular, and heteromorphic (at least in proximal part attached to calyx); columnal articular facets with moderately course short crenulae, with small transversely stellate axial canal, rays of which are directed interradially. *Upper Pennsylvanian (Missourian)*.

### CAUCACROCRINUS URNULA Moore & Strimple, n. sp.

DIAGNOSIS.—Characters of genus.

DESCRIPTION.—Upper walls of the calyx are vertical or curved very slightly inward, whereas well-curved lower ones converge to meet the small basal circle confluent (Fig. 16). Peripheral parts of the basals slope steeply upward and thus are clearly visible in side views of the calyx. The height and maximum width of radial plates are subequal or width slightly exceeds height. Most of these plates and the primanal (*X*) are hexagonal in outline but in some specimens the *B* radial is pentagonal. Approximately one third of the summit of the radials is occupied by a strongly arcuate articular facet, with shoulders on either side sloping gently to the interradial sutures. Distalmost intercalary plates are distinctly, but not greatly, smaller than the radials and primanal; lower ones decrease regularly in size toward the base. The aggregate number of these plates in the holotype and similar adult specimens exceeds 100, whereas in small juvenile individuals the number is only half as great. Intercalaries of the *A* ray and some others are arranged in longitudinal series, as are subanal ones. Most are hexagonal but some are pentagonal or heptagonal. A relatively prominent anal pyramid covered by small irregular polygonal plates is located next to the primanal plate on the posterior margin of the tegmen (Fig. 16, I-6; 17, I-7; 18, I-3). The summit is rounded and the sides slope steeply. Just in front of its base is a large subtrapezoidal posterior oral plate and near it in interradial positions are four smaller orals, all of these plates having flat smooth upper surfaces.

A few proximal columnals attached to the holotype and some paratypes display a moderately distinct heteromorphic succession, taller stem elements displaying a longitudinally convex profile and smooth sides. Around the margins of columnal articular facets are short evenly spaced

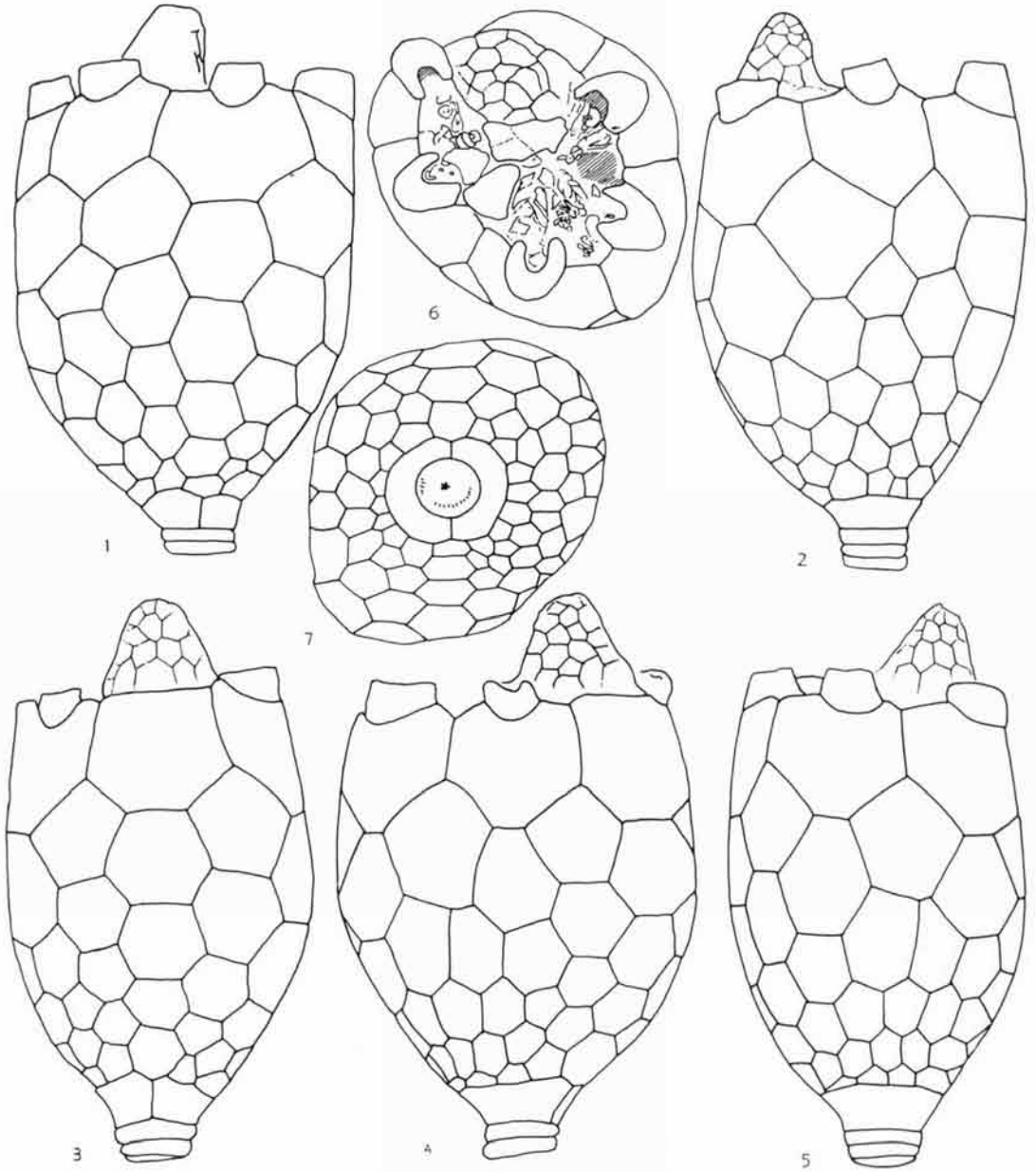


FIG. 16. *Caucacocrinus urnula* MOORE & STRIMPLE, n. gen., n. sp.

1-5. Camera lucida drawings of holotype specimen (IGS 42P87), side views of calyx looking toward *AB* inter-ray, *B* ray, *CD* inter-ray, *D* and *E* rays, all showing upflared basals, first primibrachs attached to narrowly arcuate radial articular facets, and prominent anal pyramid, all  $\times 13.5$ .

6-7. Similar views of calyx summit and base, former showing three subhorizontally disposed oral plates, posterior one largest and juxtaposed to anterior lower edge of anal pyramid, both  $\times 13.5$ .

crenulae. The small axial canal is transversely stellate in outline, with rays directed interradially.

Dimensions (in mm.) of the holotype (Fig. 16) and a juvenile paratype (IGS 42P88) (Fig.

17), the latter enclosed by parentheses are as follows. Calyx: H, 4.50 (2.60); W (maximum, at or near summit), 3.50 (2.20). *A* radial: H (midline), 1.00 (0.80); H (at interradial suture), 0.77

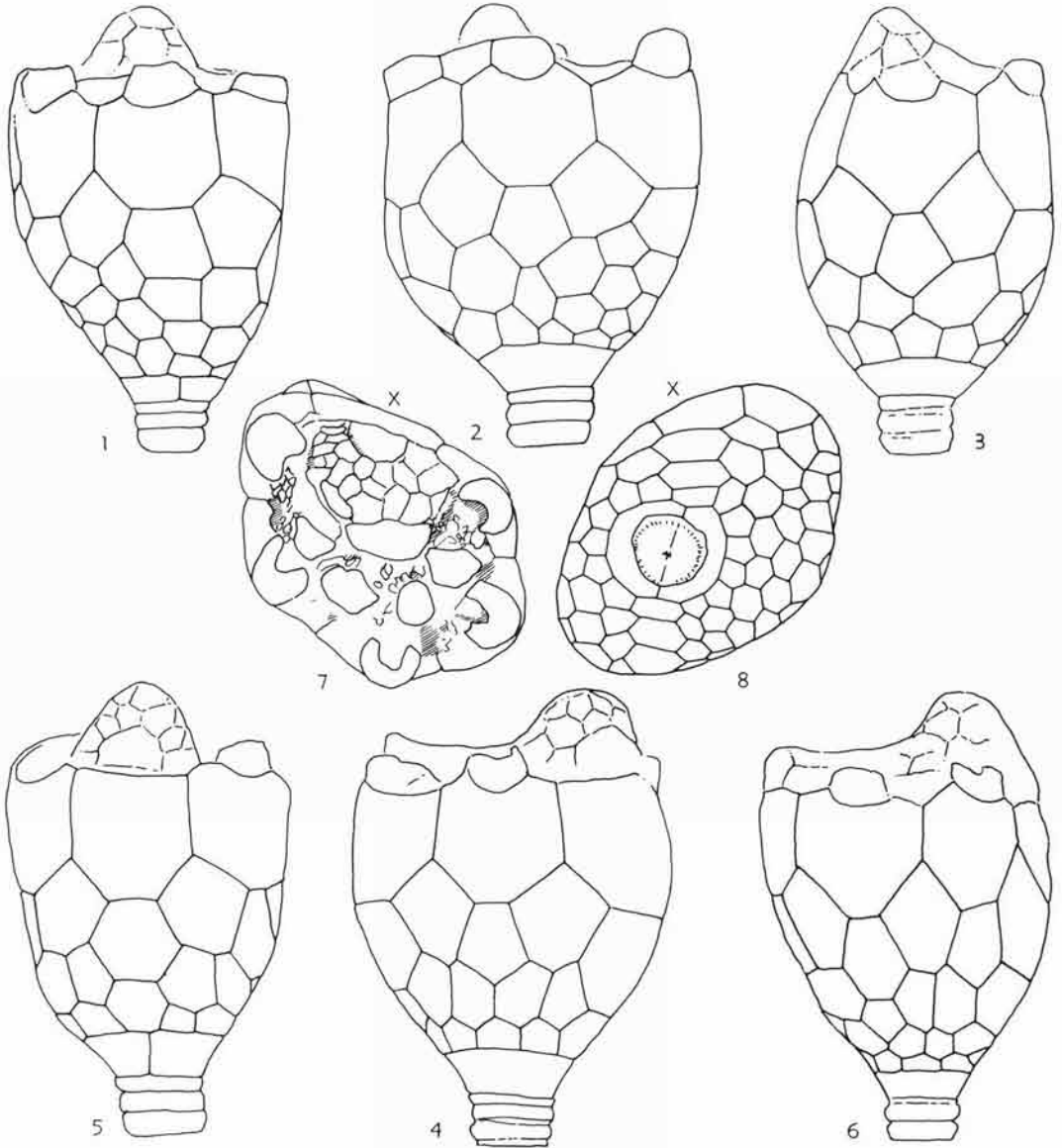


FIG. 17. *Caucacrocirinus urnula* MOORE & STRIMPLE, n. gen., n. sp.

1-6. Camera lucida drawings of juvenile specimen (paratype IGS 42P88) with attached proximal columnals, side views of calyx showing upflared periphery of basal circlet, first primibrachs in some rays, and relatively prominent anal pyramid with largest plate next to primanal, looking toward *A*, *B*, *C*, and *D* rays, and

*CD* and *DE* interrays, all  $\times 17$  (apparent variation in calyx width due to moderate lateral distortion).

7-8. Similar views of calyx summit and base, former showing five orals in front of anal pyramid, posterior oral largest (*CD* interray in upper position in both views),  $\times 17$ .

(0.55); W, 1.70 (1.00); W (articular facet), 0.59 (0.44). Subradial and subanal intercalary (same): H, 1.00 (0.63); W, 1.10 (0.70). Basal circlet: H, 0.44 (0.30); W, 1.20 (0.93); stem impression, D, 0.67 (0.63). Anal pyramid: H, 1.00 (0.59); W, 1.50 (1.00).

Two paratypes of *Caucacrocrinus urnula* call for special notice because they reveal features of the arms and stem. Both are somewhat compressed laterally and both are partly embedded in limestone matrix. The calyx of one specimen (IGS 42P95) was freed successfully, however, in preparation so that it could be viewed from all sides before gluing back in place (Fig. 19, 1a-d). This

calyx is 3.7 mm. in height and has an estimated diameter of 3.0 mm. in undistorted condition. Only a few proximal brachials belonging to the A, B, and C rays remain in association with the calyx, but except for a short missing intermediate section of the stem, this is preserved in attached position to a distance of 39 mm. beneath the calyx. The transversely circular stem is seen to be essentially homeomorphic in successive portions but markedly xenomorphic from proximal to distal regions. Near the calyx the columnals are very low, with longitudinally rounded sides. Their height gradually increases downward until at distances of more than 8 mm. height nearly

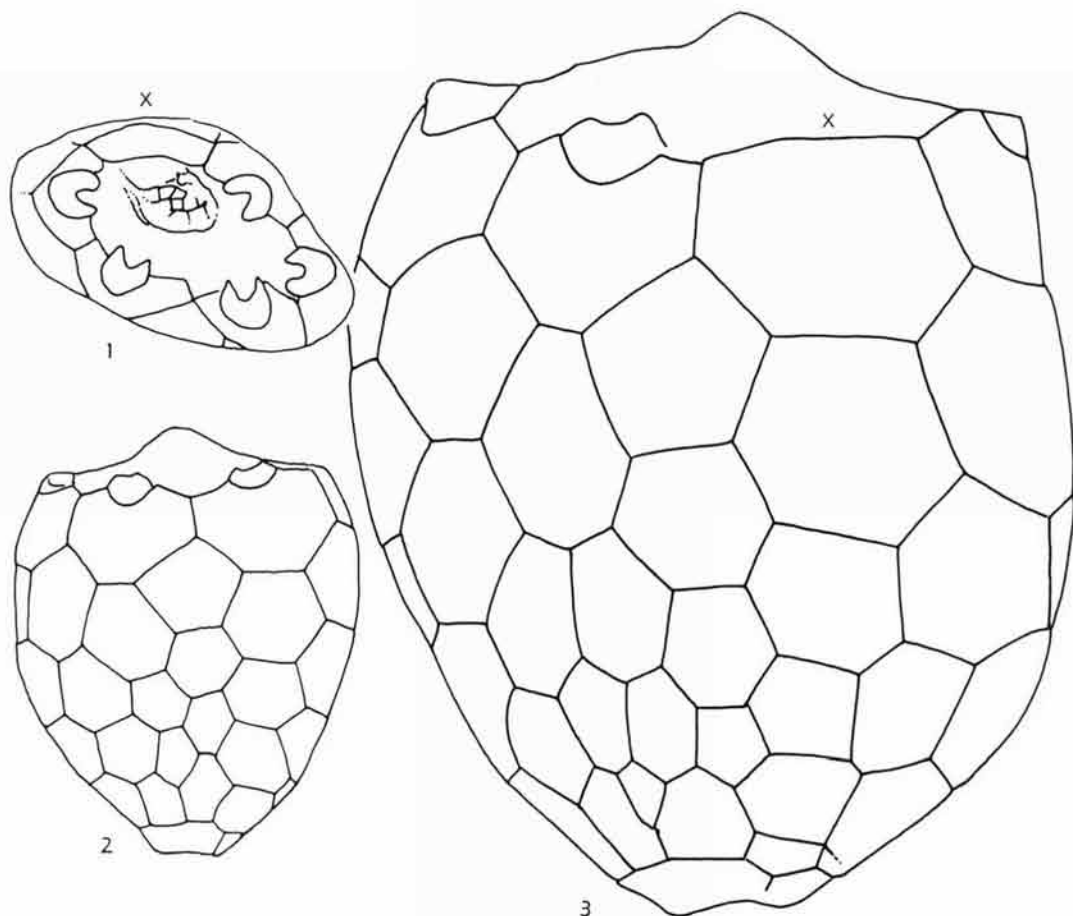


FIG. 18. *Caucacrocrinus urnula* MOORE & STRIMPLE, n. gen., n. sp.

1-2. Camera lucida drawings of paratype (SUI 32940) seen from ventral side (primanal above) and AB-inter-ray view (A radial with subjacent longitudinal series of intercalary plates near right edge), both  $\times 8.5$ .

3. Similar enlarged view of posterior side of calyx (primanal and subanal intercalary series slightly right of midline),  $\times 17$ .

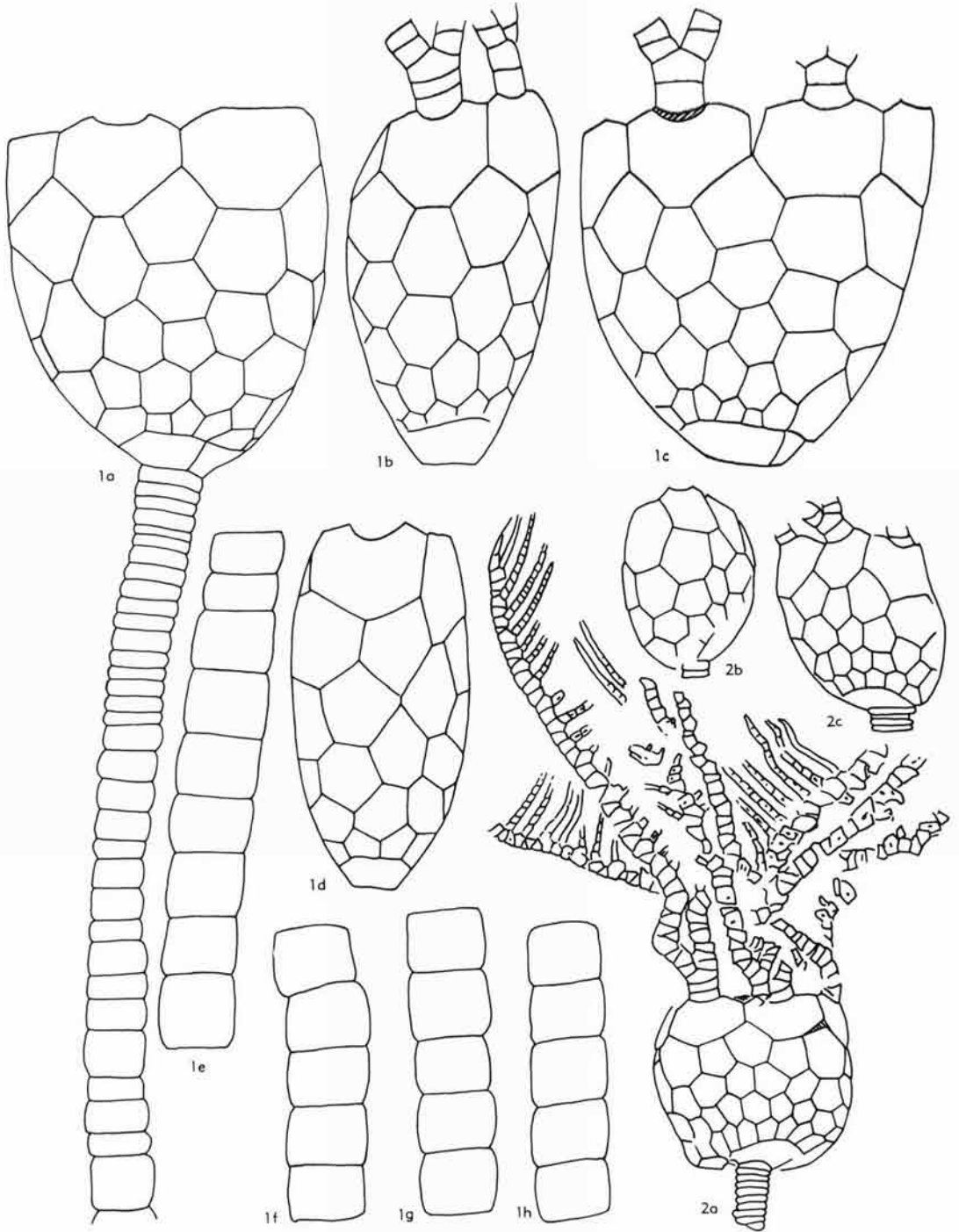


FIG. 19. *Caucareronius urnula* MOORE & STRIMPLE, n. gen., n. sp. (continued on facing page).

1. Specimen (paratype IGS 42P95) with proximal brachials preserved in some rays and long attached stem, illustrated by camera lucida drawings, all  $\times 15$ ; 1a, calyx

from *D*-ray and primanal side with proximal part of stem (7.5 mm.) joined to basal circling, showing gradual increase in height of columnals away from calyx, most



equals diameter and sides of the columnals are nearly straight longitudinally. Intercolumnal sutures are slightly indented and on many columnals a very faint row of fine granules girdles them at mid-height. The articular facets are not clearly discernible, but appear to match those illustrated in Figures 16,7 and 17,8 in having a diminutive pentastellate lumen and fine peripheral crenulae.

Arm structure exhibited by paratype IGS 42P94 (Fig. 19,2a) indicates isotomous bifurcation on primibrachs 2 or 3 (also indicated in Fig. 19,1b-c) and cuneate uniserial appearance of brachials with long pinnules, but the arms are judged to be actually biserial. The DE side of the calyx in this specimen is concealed. Height of the calyx is 3.8 mm. and its undistorted diameter is estimated to be 3.5 mm.

ILLUSTRATIONS.—FIG. 1,6. Diagram showing plate arrangement in upper part of calyx (radials black, distalmost intercalaries gray).—FIG. 16,1-7. Camera lucida drawings of holotype (IGS 42P87) in AB-interray, B-ray, CD-interray, D- and E-ray, ventral and dorsal views (anal pyramid shown in side views and oral plates and anal pyramid in ventral view), all  $\times 13.5$ .—FIG. 17,1-8. Camera lucida drawings of juvenile specimen (paratype IGS 42P88) in A-, B-, C-, and D-ray, CD- and DE-interray, ventral, and dorsal views, all  $\times 17$  (anal pyramid shown in side and ventral views of calyx and orals seen as large plates of tegmen in fig. 7; CD interray directed upward in fig. 8).—FIG. 18,1-3. Camera lucida drawings of paratype (SUI 32940); 1-2, ventral and AB-interray views,  $\times 8.5$ ; 3, posterior side of calyx (primal and subanal intercalary series slightly right of mid-line (anal pyramid broad and low),  $\times 17$ .—FIG. 19,1-2. Camera lucida drawings of paratypes attached to matrix; specimen IGS 42P95 (1a-h) with long stem and proximal parts of arms in 3 rays, all  $\times 15$ ; specimen IGS 42P94 (2a-c) with short attached stem section

and arms belonging to A, B, and C rays, all  $\times 7.5$ ; 1a-d, primal-D side of calyx with attached proximal section of stem, C-ray, AB-interray, and E sides of calyx; 1e, part of stem belonging next below 1a; 1f-h, distal sections of preserved part of stem (17 mm. of stem omitted between 1e and 1f, 1g and 1h in sequence next below 1f; 2a-c, BC-interray, C, and B-ray views of crown.

DISCUSSION.—As in other observed acrocrinids, juvenile individuals are differentiated from adults by their smaller size and smaller number of intercalary plates. In each, calyx elements and their arrangement appear to be identical.

TYPES.—Holotype, IGS 42P87a; paratypes, IGS 42P87b, IGS 42P88, IGS 42P94, IGS 42P95, SUI 32940. Collectors, H. L. STRIMPLE and CHRISTINA CLEBURN.

OCCURRENCE.—LaSalle Limestone, Missourian, Upper Pennsylvanian, Ocoya quarry near Pontiac, Livingston County, Illinois.

#### CAUCACROCRINUS ACUTUS Moore & Strimple, n. sp.

DIAGNOSIS.—Calyx with plate construction same as seen in *Caucacrocrinus urnula* but distinguished by straighter sides and more narrowly pointed base.

DESCRIPTION.—Although so far known only from the holotype, which is a complete calyx except for some of the parts of the tegmen, this seems clearly to represent a species distinct from *Caucacrocrinus urnula*. The radials are proximally truncate (narrowly so in the D ray) in all but the C ray, in which the radial is pointed proximally and not in series with an underlying subradial intercalary plate. As in *C. urnula*, the radial articular facets are narrowly arcuate and occupy approximately one-third of the width of the radials. Associated with them in three rays are first primibrachs, slightly displaced inward.

of them with faint girdling band of granules at mid-height; 1b-d, C-ray, AB-interray, and E-ray views of laterally compressed calyx; 1e, part of stem next beneath that shown in 1a (5.6 mm. in length); 1f-h, successive segments of distalmost part of preserved stem (each slightly more than 3 mm. in length), showing subquadrate outline of columnals with height approximately equal to width, lower facet of bottom columnal in 1h 39 mm. beneath base of calyx (17 mm. of intermediate part of stem omitted).

2. Specimen (paratype IGS 42P94) with large part of arms and small proximal section of stem attached to calyx, camera lucida drawings,  $\times 7$ ; 2a, crown viewed looking toward BC-interray side of calyx, arms branching isotomously on axillary primibrach 2 or 3; 2b-c, calyx from C-ray and AB-interray sides (D and E rays not visible, concealed by matrix).

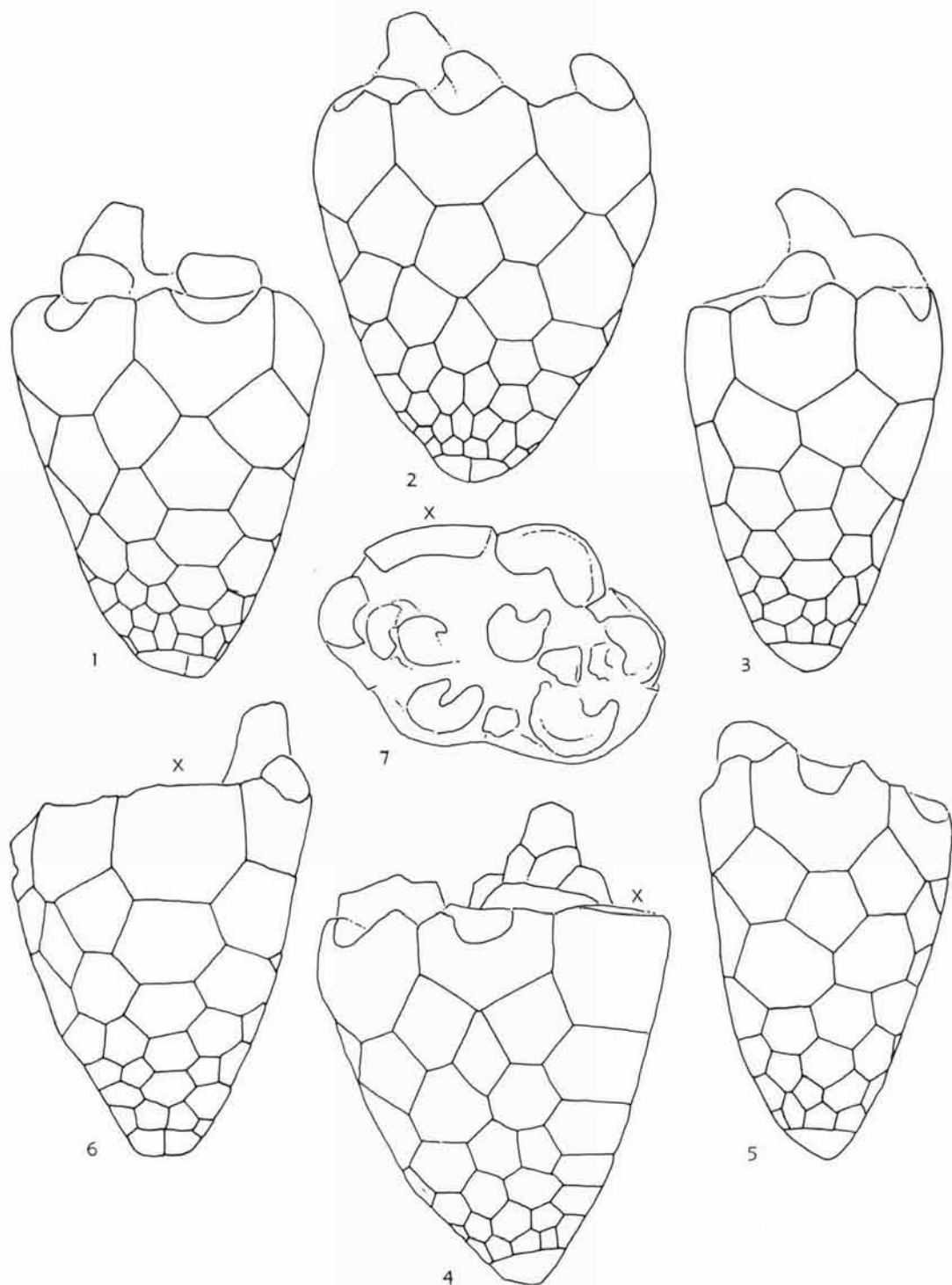


FIG. 20. *Caucacrocricinus acutus* MOORE & STRIMPLE, n. gen., n. sp. (continued on facing page).

Because the holotype of *C. acutus* possesses abundant intercalaries, it is judged to be an adult specimen. The diminutive basal cirlet has rather gently upflaring sides rather than steep ones (Fig. 20, 1-6).

No anal pyramid is preserved and only two or three tegmental plates, interpreted as displaced orals, are associated with tiny plates. Information concerning summit features of the calyx is lacking.

Dimensions (in mm.) of the holotype specimen are as follows. Calyx: H, 3.3; W, 2.6. *A* radial: H, (mid-line), 0.8; H (interradial suture), 0.6; W, 1.2; articular facet W, 0.7. Subradial and subanal intercalary: H, 0.8; W, 0.9. Basal cirlet: H, 0.2; W, 0.6.

ILLUSTRATIONS.—FIG. 20, 1-7. Camera lucida drawings of holotype in *A*-, *B*-, *C*-, *D*-, and *E*-ray, *CD*-interray, and ventral views of calyx, all  $\times 17$  (*CD* interrayer directed upward in fig. 7).—FIG. 21, 3a,b. Holotype in *A*-ray and *CD*-interrayer views,  $\times 7$ .

TYPE.—Holotype, IGS 42P89; collected by CHRISTINA CLEBURN.

OCCURRENCE.—LaSalle Limestone, Missourian, Upper Pennsylvanian, Ocoya quarry near Pontiac, Livingston County, Illinois.

### Genus METACROCRINUS Moore & Strimple, n. gen.

TYPE SPECIES. — *Acrocrinus pumpkensis* STRIMPLE, 1949, p. 900, fig. 2, pl. 1, fig. 1-3.

DIAGNOSIS.—Differs from *Dinacrocrinus* only in absence of intercalary plate directly beneath *D* radial (Fig. 1, 8). *Middle Pennsylvanian (Desmoinesian)*.

DESCRIPTION.—The calyx is subglobular in shape, broadly rounded below and somewhat truncate at the summit. The radials and primanal are distinctly, though not greatly larger than upper and intermediate intercalaries and lowermost intercalaries are unusually few (11 in the holotype of the type species) and large.

### METACROCRINUS PUMPKENSIS (Strimple), Moore & Strimple, n. comb.

*Acrocrinus pumpkensis* STRIMPLE, 1949, p. 900, fig. 2, pl. 1, fig. 1-3.

DIAGNOSIS.—Characters of genus.

DESCRIPTION.—The hexagonal radials (except pentagonal in *D* ray) are widest at mid-height and in all the height is only one half or less of width. These plates are especially characterized by their strongly curved articular facets, which occupy one-fourth of the summit radial width (Fig. 21, 2b-c). The primanal (*X*) plate is somewhat larger than adjoining radials and has height equal to width; it is hexagonal in outline but appears almost quadrangular. The intercalaries are relatively large, even near the base of the calyx, and in accordance with this their aggregate number is comparatively small (62 in the holotype specimen). The flat basal cirlet, 3.2 mm. in diameter, is nearly three times as wide as proximal columnals, 1.2 mm. in width. Plates of the calyx are smooth and evenly confluent with neighbors, but sutures between them are very sharply defined.

Dimensions of the holotype (in millimeters), some slightly modified from first-published figures, are as follows. Calyx: H, 9.5; W, 7.5. *A* radial: H (at mid-width), 1.5; H (at interradyal sutures), 1.0; W (maximum), 3.2; W (at base), 1.5. Primanal (*X*) plate: H, 2.9; W, 3.0.

ILLUSTRATIONS.—FIG. 1, 8. Diagram of calyx plates (radials black, distalmost intercalaries gray) (Strimple, 1949, mod.).—FIG. 21, 2a-c. Holotype in dorsal, *D*-ray (slightly left of mid-line), and *EA*-interrayer views, all  $\times 4$  (Strimple, 1949).

DISCUSSION.—This species resembles *Dinacrocrinus expansus* STRIMPLE in general shape of the calyx, large size of the intercalaries, and relatively small number of these plates—so much so that the difference in morphology of the *D* ray is not now reliably interpretable as a basis for generic distinction. Additional specimens of both species are needed to establish constancy of their structure as presently known.

TYPE.—Holotype, U. S. Natl. Museum S4749. Collected by W. T. WATKINS.

1-6. Camera lucida drawings of holotype specimen (IGS 42P89) in side views looking toward *A*, *B*, *C*, *D*, and *E* rays, and *CD* interrayer, all showing pointed lower extremity of calyx with low but distinctly visible basal cirlet, all  $\times 17$ .

7. Similar drawing of calyx summit showing some first primibrachs and displaced orals (primanal above and slightly toward left),  $\times 17$ .

**OCCURRENCE.** — Lake Murray Formation (Pumpkin Creek Limestone Member), lower Desmoinesian, Middle Pennsylvanian; west side of Lake Murray, south of Ardmore, Carter County, Oklahoma.

### Genus *DINACROCRINUS* Moore & Strimple, n. gen.

**TYPE SPECIES.**—*Acrocrinus expansus* STRIMPLE, 1951, p. 192, fig. 1, 17-20; original designation herein.

**DIAGNOSIS.**—Calyx rotund, truncate at summit of radials, basals barely visible from side or not visible; differing from *Globacrocrinus* in occurrence of 12 intercalaries next beneath radial cirlet, 5 subradial, with longitudinal series of intercalaries under *A* radial and primanal (Fig. 1,7). *Middle Pennsylvanian (Desmoinesian)*—*Upper Pennsylvanian (Missourian)*, USA (Oklahoma-Illinois).

**DESCRIPTION.**—Calyx with flat to very gently convex or concave base, approximately 0.6 of greatest calyx width located at about 0.35 of calyx height, where sides are strongly and evenly rounded, upper sides of calyx nearly vertical or sloping evenly inward to summit, which is 0.6 to 0.9 of greatest width in distance across between opposite radial margins.

**DISCUSSION.**—Superficially, *Dinacrocrinus* resembles *Globacrocrinus*, for in shape and average dimensions of the calyx, as well as in the narrow width of the arcuate radial articular facets, one could almost be mistaken for the other. The prime distinction between the two genera is found in the number and arrangement of distalmost intercalary plates, which are 12 in *Dinacrocrinus*, with one such plate directly beneath each radial and the primanal, whereas in *Globacrocrinus* total plates in this cirlet number eight, with only the *A* radial and primanal followed directly beneath by an intercalary plate. In so far as now known, *Globacrocrinus* is restricted to Lower and Middle Pennsylvanian formations, whereas *Dinacrocrinus* occurs in Middle and Upper Pennsylvanian beds.

### *DINACROCRINUS EXPANSUS* (Strimple), Moore & Strimple, n. comb.

*Acrocrinus expansus* STRIMPLE, 1951, p. 192, fig. 1, 17-20.

**DIAGNOSIS.**—Characters of genus.

**DESCRIPTION.**—The shape of the calyx in this

species is tomato-like, with flat, faintly concave base, strongly rounded lower sides, and evenly inward sloping upper sides. The holotype of the type species, which is 8.4 mm. high, has maximum width of 10.0 mm. and width at summit of the radials amounting to 6.2 mm. The radials and primanal, approximately 2 mm. high by 3 mm. wide, are very little larger than the upper and middle intercalary plates. The strongly arcuate radial facets occupy 0.7 of the distal width of these plates and their concave surface is nearly as broad from outer to inner edges as from lateral margins. Diameter of the basal cirlet is 2 mm.

**ILLUSTRATIONS.**—FIG. 21,4a-d. Holotype in ventral, dorsal, *CD*-interray, and *A*-ray views, all  $\times 4$  (*CD* interrayer directed upward in fig. 4a and 4b) (Strimple, 1951). [Also see FIG. 1,7.]

**TYPE.**—Holotype, U. S. Natl. Museum, no. S4901. Collected by H. L. STRIMPLE.

**OCCURRENCE.**—Oologah Ls., Desmoinesian, quarry about 7 miles east of Tulsa, Oklahoma.

### *DINACROCRINUS ELEGANS* (Strimple), Moore & Strimple, n. comb.

*Acrocrinus elegans* STRIMPLE, 1949, p. 903, pl. 1, fig. 4-6, text-fig. 2.

**DIAGNOSIS.**—Characters of genus but differing from its type species in having slightly upflaring basals which are visible from side and in relatively tall urn-shaped form of calyx; tegmen with low anal pyramid near posterior margin.

**DESCRIPTION.**—The slightly deformed holotype specimen, which is the only representative of the species yet found, is evenly rounded in its lower part and nearly vertical-sided from mid-height of the calyx to the summit of the radial cirlet. Height of the calyx is 9.3 mm. and greatest width approximately 7.0 mm. The intercalaries are smaller in average size than in *Dinacrocrinus expansus* and more numerous.

**ILLUSTRATIONS.**—FIG. 21,1a-c. Holotype in *A*-ray, *CD*-interray, and dorsal views of calyx, all  $\times 4$  (*CD* interrayer directed upward in fig. 1c) (Strimple, 1949).

**TYPE.**—Holotype, U. S. National Museum no. S4750. Collected by H. L. STRIMPLE.

**OCCURRENCE.**—Shale above Torpedo Sandstone, Ochelata Group, Upper Pennsylvanian (upper Missourian), 2.5 miles NE of Copan, Washington County, Oklahoma.

**DINACROCRINUS WORTHENI**  
(Wachsmuth), Moore & Strimple, n. comb.

*Acrocrinus wortheni* WACHSMUTH, 1882, p. 41.—  
WACHSMUTH & BARRIS, 1883, p. 343, pl. 30, fig. 13.  
—WACHSMUTH & SPRINGER, 1885, p. 125, pl. 9, fig.  
1; 1897, p. 807, pl. 80, fig. 10a-b.—SPRINGER, 1926,  
p. 45, pl. 12, fig. 10.

DIAGNOSIS.—Differs from type and other species of genus in diminutive size of calyx, its subvertical sides, and width at summit nearly equal to maximum width and that just above flatly rounded base.

DESCRIPTION.—Height and maximum width of the calyx are about 5.5 mm. and 5.3 mm., re-

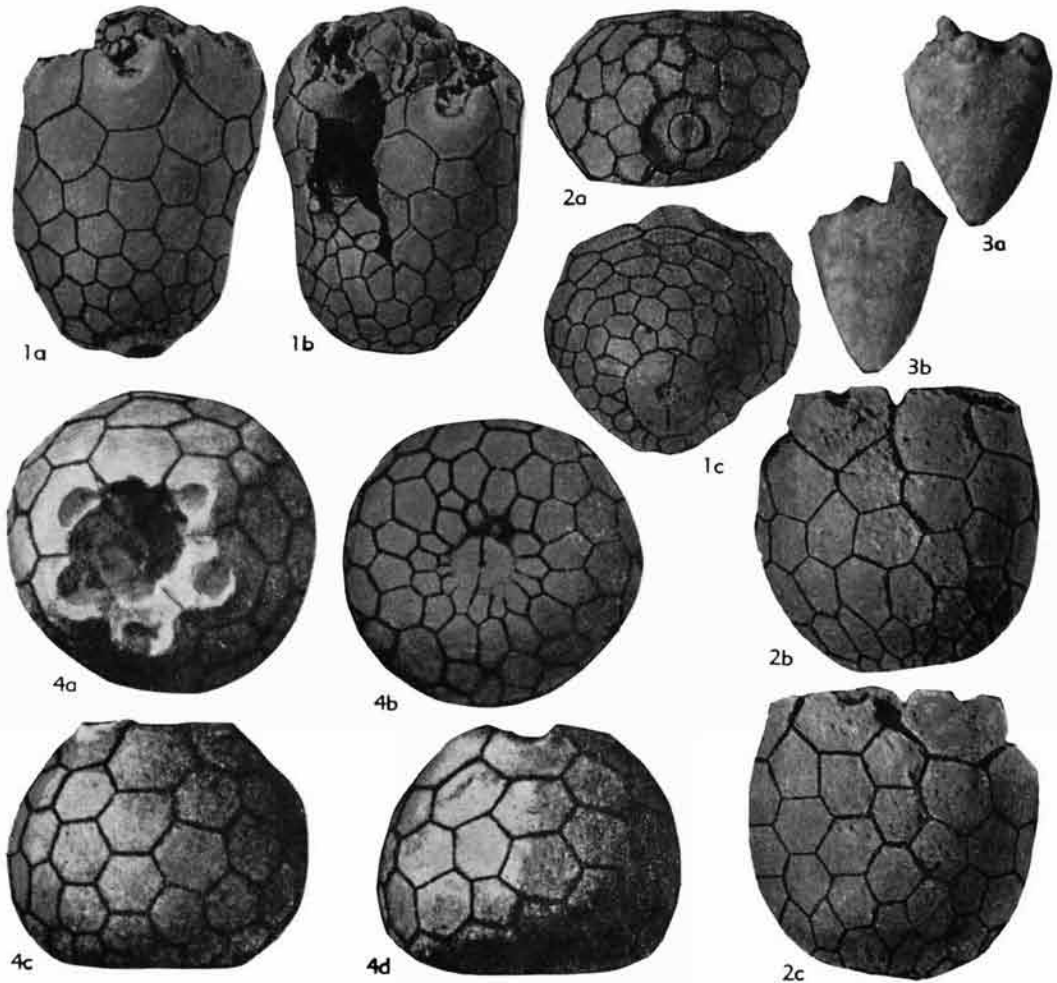


FIG. 21. *Dinacrocrinus*, *Metacrocrinus*, and *Caucaeroocrinus*, all MOORE & STRIMPLE, n. gen.

1. *Dinacrocrinus elegans* (STRIMPLE), MOORE & STRIMPLE, n. comb.; holotype specimen (USNM S4750); 1a-c, A-ray, CD-interray, and dorsal views of calyx (CD interray directed upward in 1c), all  $\times 4$  (Strimple, 1949).
2. *Metacrocrinus pumphensis* (STRIMPLE), MOORE & STRIMPLE, n. comb.; holotype (USNM S4749); 2a-c, dorsal view (CD interray directed upward), posterior side of calyx (primanal slightly right of mid-line), and EA-interray view of calyx, all  $\times 4$  (Strimple, 1949).
3. *Caucaeroocrinus acutus* MOORE & STRIMPLE, n. sp., holotype (IGS 42P89); 3a-b, side views of calyx looking toward A ray and CD interray,  $\times 7$ .
4. *Dinacrocrinus expansus* (STRIMPLE), MOORE & STRIMPLE, n. comb.; holotype (USNM S4901); 4a-d, ventral and dorsal views of calyx (both with CD interray directed upward), and side views looking toward CD interray and A ray, all  $\times 4$  (Strimple, 1951).

spectively. The radials are appreciably wider than high and have broadly arcuate articular facets. Intercalaries mostly hexagonal in outline and except near the base of the calyx fairly similar in size. Their arrangement exactly conforms to that given in diagnosis of the genus, with 12 plates in the distalmost cirlet and longitudinal series beneath the *A* radial and primanal. Despite the small size of the calyx, the holotype contains 86 plates (5 radials, primanal, 2 basals, 78 intercalaries) (Fig. 22,1).

ILLUSTRATIONS.—FIG. 22,1-3. Holotype specimen; 1, plate diagram (modified from Wachsmuth & Springer, 1885); 2-3, *A*-ray and *BC*-inter-ray side views of calyx,  $\times 12$  (after Wachsmuth & Barris, 1883).

TYPE.—Holotype (only recorded specimen), originally deposited in Illinois State Museum at Springfield, now Illinois Geological Survey, no. IGS 2469.

OCCURRENCE.—Exact stratigraphic and geographic source of type is unknown, because merely reported from "Upper Coal Measures, Peoria County, Illinois." According to H. R. WANLESS, marine Pennsylvanian strata of this county include the St. David, Brereton, and Lonsdale limestones (upper Desmoinesian) and Trivoli Limestone (lower Missourian). Thus, *Dinacrocrinus wortheni* may belong either to upper Middle Pennsylvanian, approximately equivalent in age to *D. expansus*, or to lowermost Upper Pennsylvanian, corresponding more or less closely to the horizon of *D. elegans*.

### PROTACROCRINUS Moore & Strimple, n. gen.

TYPE SPECIES.—*Acrocrinus primitivus* LAUDON & BEANE, 1937, p. 252.

DIAGNOSIS.—Crown pyriform, with ten biserial arms bearing long slender pinnules. Calyx deep bowl-shaped, evenly rounded at base, truncate at top, composed of five small radials which are subequal in height and width, primanal rising slightly above summit of radials, six tall intercalaries directly beneath radials and primanal, and two basals (Fig. 1,2). Stem impression very small, stem unknown. Lower Mississippian (*Kinderhookian*).

DISCUSSION.—As noted in general discussion of the Acrocrinidae, *Protacrocrinus* is the oldest

known representative of the family and its complement of only 14 plates in the calyx makes this genus decidedly the most simple in structure. *Protacrocrinus* is not smallest in size, for the height and diameter of the calyx of *P. primitivus* are two or three times greater than corresponding measurements of *Planacrocrinus minutus* and *Caucacrocrinus acutus*. The shape of the calyx differs little from that of the former species and some forms of *Globacrocrinus*.

### PROTACROCRINUS PRIMITIVUS (Laudon & Beane), Moore & Strimple, n. comb.

*Acrocrinus primitivus* LAUDON & BEANE, 1937, p. 252, pl. 17, fig. 5-6.

DIAGNOSIS.—Characters of genus.

DESCRIPTION.—The relatively tall, transversely subcircular calyx is chiefly characterized by its evenly rounded base, with basal cirlet nearly one-third of total calyx height (Fig. 23,2-7; 24,1a-b). The radials are small plates which in views directly normal to their mid-points and with summit margins drawn straight from shoulder to shoulder (ignoring deeply arcuate articular facets) are hexagonal in the *C* and *D* rays and pentagonal in others (Fig. 23,1). The *A* and *B* radials are distinctly smaller than the intercalaries beneath them, whereas the *C*, *D*, and *E* radials are approximately equal in size to the subradial intercalaries associated with them. These intercalaries are quadrangular in the *C* and *D* rays, pentagonal in the *E* ray, and hexagonal in others (Fig. 23,2-5,7). All are taller than wide. The *A*, *E*, and subanal intercalaries are slightly offset toward right, with oblique shoulders at upper right margins. (Fig. 23,2,6-7). The *A* and *CD* intercalaries are pointed at their lower edges to match beveled shoulders of the basals next to the interbasal suture. The strongly curved radial articular facets are narrow, occupying little more than one-third of the radial summit. All calyx plates are smooth. Sutures between them are distinct but not impressed.

The arms are very well rounded externally. Primibrach 1 and axillary primibrach 2 are low plates, less than half of width in height. They lack pinnules. Lowermost brachials of the ten arms are cuneate in shape, with pinnules borne by upper angles of their taller margins. Biserial structure of the arms is attained at levels of the fourth or fifth secundibrachs. The long slender pinnules are composed of short pinnulars, with

length 1.5 to 2 times width. The arms of the holotype rise almost vertically from the calyx, curve outward, and toward summit of the crown bend inward. They are nearly uniform in narrow width throughout most of their height, but as expected taper somewhat distally.

A small stem impression is barely perceptible.

Dimensions of the crown, calyx, and plate elements of the holotype of *Protacrocrinus primitivus* expressed in millimeters and given in terms of height (H), width (W), diameter (D), and length (L) are as follows. Crown: H, 25. Calyx:

H, 7.0; D, 5.0. Radials, given as H and (W): A, 2.7 (3.1); B, 2.3 (2.3); C, 2.5 (2.8); D, 1.9 (2.3); E, 2.3 (2.3). Primal: H, 1.9; W, 1.5. Intercalaries, given as for radials: A, 4.1 (2.5); B, 3.8 (3.1); C, 2.8 (1.8); D, 2.3 (1.8); E, 2.8 (2.1); subanal, 4.1 (2.3). Basal cirlet: H, 1.9; D, 3.7.

ILLUSTRATIONS.—FIG. 23, I-7. Camera lucida drawings of holotype and component elements of its calyx, all  $\times 8.5$ ; I, radial and primal plates viewed perpendicularly toward their mid-points (broken lines across arcuate articular facets of radials; 2-7, side views of calyx from A, B, C, D,

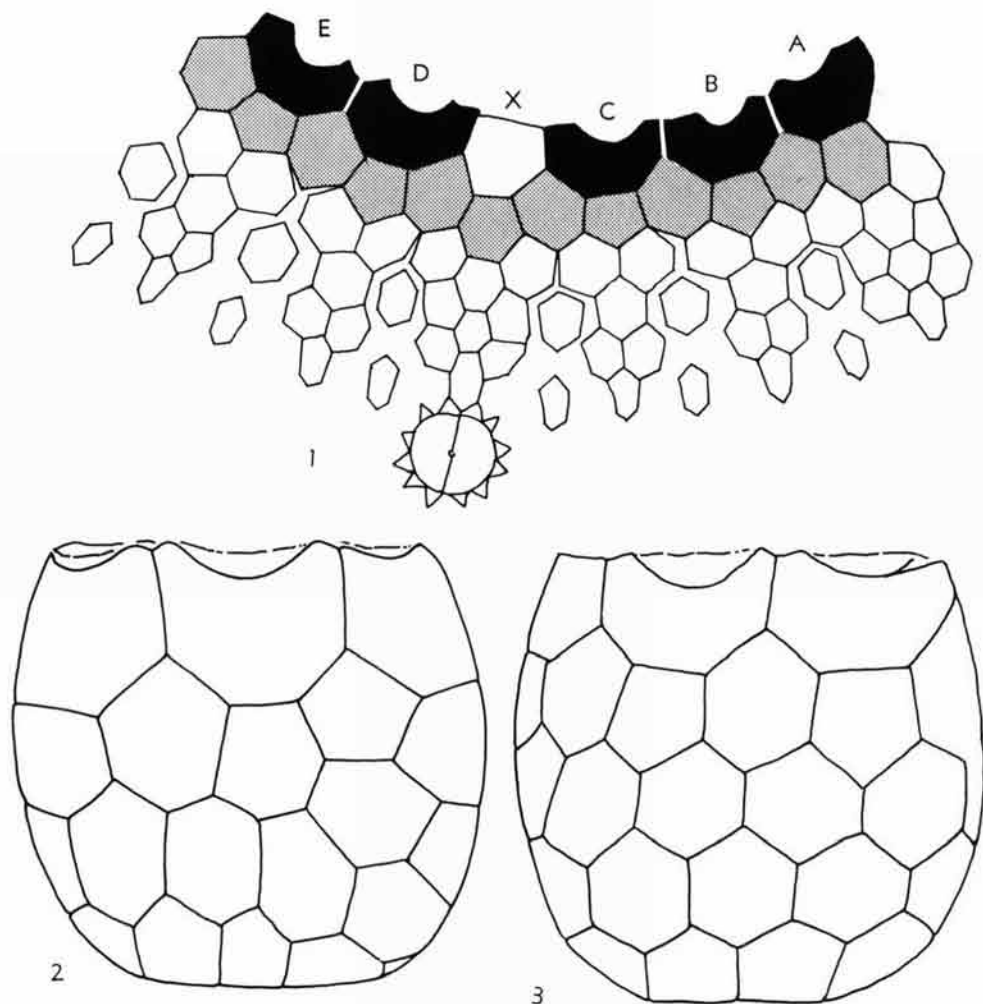


FIG. 22. *Dinacrocrinus wortheni* (WACHSMUTH), MOORE & STRIMPLE, n. comb; holotype (IGS 2469).

1. Plate diagram of entire calyx showing primal (X) plate, Carpenter-lettered radials (black), and distal-most intercalaries (gray) (modified from Wachsmuth & Springer, 1885).

2-3. Drawings of calyx seen from A-ray and BC-interray sides,  $\times 10$  (after Wachsmuth & Barris, 1883).

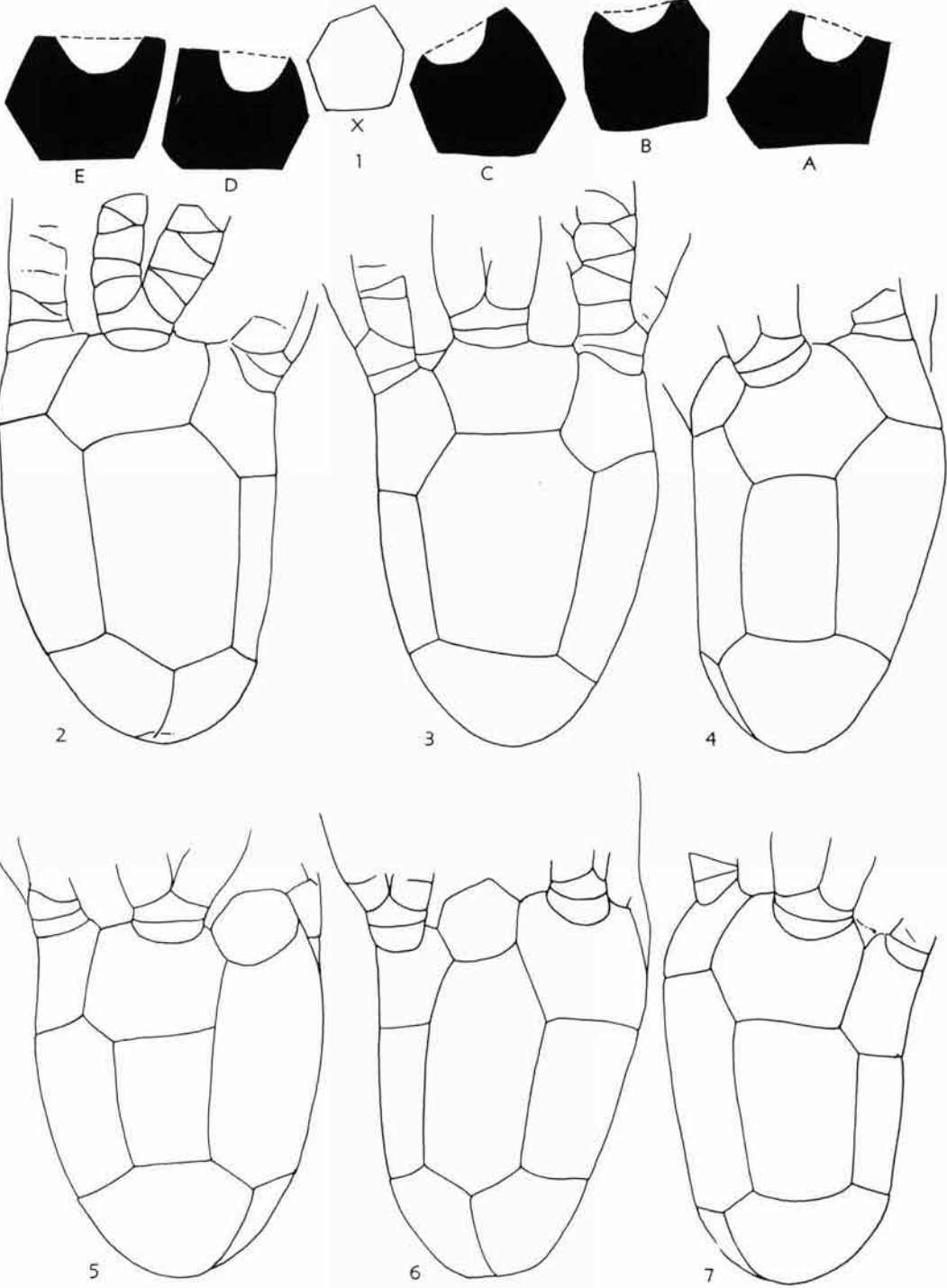


FIG. 23. *Protacrocrinus* MOORE & STRIMPLE, n. gen. (continued on facing page).



*CD*, and *E* rays and interray.—FIG. 24, 1*a-b*. Holotype crown viewed from *B*- and *D*-ray sides,  $\times 2.25$ . [Also see FIG. 1, 2.]

TYPE.—Holotype, SUI 2144, collected by B. H. BEANE.

OCCURRENCE.—Hampton Formation, Lower Mississippian (Kinderhookian), LeGrand, Tama County, Iowa.

### SPRINGERACROCRINUS Moore & Strimple, n. gen.

TYPE SPECIES. — *Acrocrinus intermedius* SPRINGER, 1926, p. 43.

DIAGNOSIS.—Calyx urn-shaped, with steep gently curved sides and widest at summit, or elongate sausage-shaped and constricted in width at summit; basals upflaring, clearly visible in side views; differs from other genera of subfamily in interradial placement of all distalmost intercalaries, with total of seven plates in this circle (Fig. 1, 10). Low anal pyramid near posterior margin of tegmen, or not observed. Arms, where known, long and slender, short proximal portion composed of uniserial brachials without pinnules and branching once or twice isotomously, remainder of arms unbranched, composed of biserially arranged brachials, each of which bears long pinnule. Stem long and slender, homeomorphic, composed of low columnals. Lower Mississippian (*Osagian*) to Upper Mississippian (*Chesteran*), USA (Illinois-Iowa); Middle Carboniferous (*Moscovian*), USSR (Moscow basin).

DISCUSSION.—Chief distinguishing characteristics of *Springeracrocricinus* are its relatively tall radials, large primanal followed below by a longitudinal series of subanal intercalaries, interradial location of all distalmost intercalaries and distinctly upflared marginal parts of basals. Intercalaries range from a small number in species with a subconical or urn-shaped calyx to a large number in the sausage-like *S. mjatschkowensis* of Russia.

### SPRINGERACROCRINUS INTERMEDIUS (Springer), Moore & Strimple, n. comb.

*Acrocrinus intermedius* SPRINGER, 1926, p. 43, pl. 12, fig. 2-5.

DIAGNOSIS.—Calyx subconical, urn- or vase-shaped, widest at summit; otherwise with characters of genus.

DESCRIPTION.—The radial plates are pentagonal in outline, with height little less than width, their average height amounting to one-third that of the calyx; their arcuate articular facets are narrow, occupying only one-fourth to one-third of the distal margin of the radials, with shoulders on either side subhorizontal or sloping very gently downward to the interradial sutures (Fig. 24, 3-6). The hexagonal primanal (*X*) plate is somewhat wider and a little taller than the radials and is distinguished by its very wide, gently curved summit margin next to a low anal pyramid at the posterior edge of the tegmen. The intercalary plates range in shape from pentagonal to hexagonal or heptagonal. All are distinctly smaller than the radials. Outer parts of the basal plates slope steeply upward in line with curvature of the calyx sides; the height of peripheral parts of these plates may exceed the diameter of the basal circle at its horizontal lower portion. All plates of the calyx are smooth and either plane or very slightly tumid.

The slender, externally well-rounded arms bifurcate evenly on primibrach 2 and commonly in one of the branches on secundibrach 2. The brachials are uniserially arranged beneath the axillary secundibrach of branched arms and near the base of the unbranched arm above an axillary primibrach and all of these lack pinnules. Distally, the brachials first become cuneate in external outline and then quickly assume a biserial arrangement, each brachial in these parts of the arms bearing very long slender pinnules. The pinnules are composed of unusually long narrow pinnulars. In such specimens the distal parts of the arms curve strongly inward at summit of the crown.

1. *Protacrocricinus primitivus* (LAUDON & BEANE), MOORE & STRIMPLE, n. comb.; camera lucida drawings of radials and primanal viewed perpendicularly to centers of these plates (broken lines drawn straight across arcuate radial articular facets from their lateral margins for the purpose of indicating shape of these plates in overall outline),  $\times 8.5$ .

2-7. Same, calyx and proximal arm extremities of holotype specimen (SUI 2144); camera lucida drawings of *A*-, *B*-, *C*-, and *D*-ray, *CD*-interray, and *E*-ray sides of calyx showing varied shapes of intercalaries and bowl-like bipartite basal circle, all  $\times 8.5$ .

The slender part of the stem near the base of the calyx is composed of very low columnals. In intermediate and distal parts of the stem the columnals increase in height and diameter, with longitudinally even-rounded sides. The nature of the columnal articular facets and axial canal is not recorded.

Dimensions of specimens illustrated by SPRINGER (1926, pl. 12) are as follows. Crown: H, 21 (fig. 2), 28 (fig. 5). Calyx (respectively fig. 2-5): 7, 6, 7, 7; W, 5, 5, 5.5, 6. Primal (fig. 2): H, 2.0; W, 2.2. Average radial: H, 1.5, 1.7, 2.5, 2.0; W, 1.5, 2.0, 2.5, 2.0. Basal circle: H, 1.5; W, 2.5.

ILLUSTRATIONS.—FIG. 24,3-6. Side views of type specimens; 3, lectotype crown viewed from C-ray side, primal and subanal intercalary series near left edge of photo,  $\times 3.4$ ; 4-5, C- and F-ray views of paralectotypes,  $\times 3.4$ ; 6, A-ray view of paralectotype crown,  $\times 1.7$  (Springer, 1926). [See FIG. 1,10 also.]

TYPES.—Syntypes (SI578) deposited in Springer collection, U. S. National Museum. The specimen illustrated by SPRINGER (1926) in figure 2 of his plate 12 is here designated as the lectotype and others as paralectotypes.

OCCURRENCE.—Renault Formation, Upper Mississippian (lower Chesteran), near Burksville, Monroe County, Illinois.

### SPRINGERACROCRINUS MJATSCHKOWENSIS (Yakovlev), Moore & Strimple, n. comb.

*Acrocrinus mjatschkowensis* YAKOVLEV, 1926, p. 47, fig. 3-4.—YAKOVLEV & IVANOV, 1956, p. 34, pl. 8, fig. 7a-b.

DIAGNOSIS.—Construction of radial circle and large primal in CD interray, arrangement of distalmost intercalaries, occurrence of subanal intercalaries in longitudinal series, and bipartite basal circle with upflaring periphery all as in *Springeracrocrinus intermedius*, but distinguished from this species by tall sausage-like, ovoid form of calyx and large number of nearly even-sized intercalaries.

DESCRIPTION.—Most of the sides of the calyx representing *Springeracrocrinus mjatschkowensis* are nearly straight and vertical but toward the summit and base they curve inward to produce rounded extremities (Fig. 24,7b). The pentagonally shaped radials have subequal height and width

and are narrowest at distal margins which are indented by arcuate articular facets narrower than the summit width of these plates. The primal is slightly larger than the radials, hexagonal in outline, and its distal edge is slightly below the level of the radial summits. Beneath it in longitudinal series are three subanal intercalaries but lower plates on the posterior side of the calyx do not continue this series. Nine or ten transversely disposed circlelets of intercalaries are recognized, with moderate regularity in their arrangement.

Dimensions (in mm.) of the calyx and component elements are as follows. Calyx: H, 10.3; W, 5.1. Radials (average) H and W, 1.7. Primal: H, 1.7; W, 2.0. Basal circle: H, 0.8; W, 3.5.

DISCUSSION.—Despite dissimilarity of *Springeracrocrinus mjatschkowensis* in shape of its calyx as compared with *S. intermedius* and *S. praecursor*, with very little hesitation the Russian species is considered congeneric with the American ones. Chief interest lies in its very elongate modified calyx form and large number of intercalary plates, along with this is its occurrence in eastern Europe in beds approximately equivalent to Middle Pennsylvanian of the United States.

ILLUSTRATIONS.—FIG. 24,7a-b. Ventral and CD-interray views of type specimen,  $\times 4.5$  (Yakovlev & Ivanov, 1956).

OCCURRENCE.—Middle Carboniferous (Myachkovian) (C<sub>2</sub>m). Moscow basin, southeast of Moscow, USSR.

### SPRINGERACROCRINUS PRAECURSOR (Springer), Moore & Strimple, n. comb.

*Acrocrinus praecursor* SPRINGER, 1926, p. 42, pl. 12, fig. 1.

DIAGNOSIS.—Differs from *Springeracrocrinus intermedius* chiefly in larger number of intercalaries, straight slender arms composed of cuneate uniserial brachials alternately bearing pinnules on opposite sides of arms, seemingly ten but branching just above calyx not preserved.

DESCRIPTION.—This species is based on a single incomplete crown with somewhat crushed calyx, which is deeply subconical, as in *Springeracrocrinus intermedius* (Fig. 24,2). Its quadrati-pentagonal radials are subequal in height and width, with comparatively shallow arcuate articular facets. The primal (X) plate resembles these but is hexagonal in outline and directly

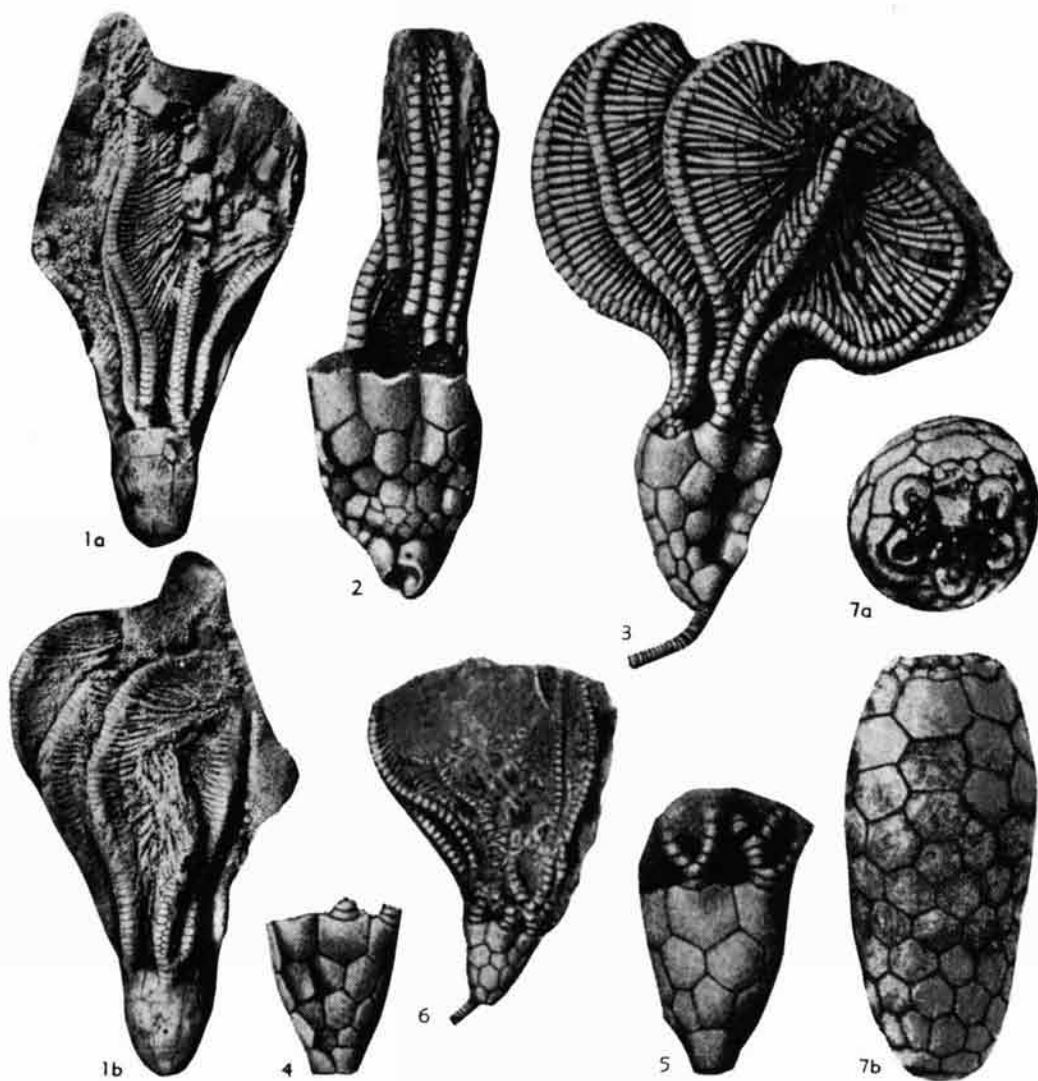


FIG. 24. *Protacrocrinus* and *Springeracrocrinus* MOORE & STRIMPLE, n. gen.

1. *Protacrocrinus primitivus* (LAUDON & BEANE), MOORE & STRIMPLE, n. comb.; holotype crown (SUI 2144); 1a-b, views of specimen from B- and D-ray sides,  $\times 2.25$  (Moore & Strimple, new).
2. *Springeracrocrinus praecursor* (SPRINGER), MOORE & STRIMPLE, n. comb.; holotype (USNM S1779), showing posterior side of crown (primanal centrally located at summit of calyx), somewhat crushed specimen with well-marked upflaring equal basals,  $\times 1.7$  (Springer, 1926).
- 3-6. *Springeracrocrinus intermedius* (SPRINGER), MOORE &

STRIMPLE, n. comb.; lectotype (USNM S1578a (fig. 3) and paralectotypes (USNM S1578b-d) (fig. 4-6); 3, crown viewed from C-ray side (primanal and subanal intercalary series near left edge of photo),  $\times 3.4$ ; 4-5, C- and E-ray views of calices showing tall upflared basal circlelet,  $\times 3.4$ ; 6, A-ray view of crown,  $\times 1.7$  (Springer, 1926).

7. *Springeracrocrinus mjatschkowensis* (YAKOVLEV), MOORE & STRIMPLE, n. comb.; type specimen; 7a-b, ventral and CD-interray views of calyx with associated first primibrachs,  $\times 4.5$  (Yakovlev & Ivanov, 1956).

underlain by a series of intercalaries. Other intercalary plates in the distal most cirlet are interradial but arrangements of these plates in lower cirlets becomes disordered. The basal cirlet is truncate proximally and has steeply upflaring sides.

Dimensions (in mm.) of the type specimen are as follows. Calyx: H, 9.0 (illustration given by SPRINGER, reported to be  $\times 1$ , is actually  $\times 2$ );

W, 7.5. Radials (average): H, 2.5; W, 2.5. Basal cirlet: H, 1.5; W, 3.5.

ILLUSTRATIONS.—FIG. 24.2. Posterior view of crown,  $\times 1.7$  (Springer, 1926).

TYPE.—Holotype (S1779) reposit in U. S. National Museum.

OCCURRENCE.—Upper Burlington Limestone, Lower Mississippian (Osagian), Burlington, Iowa.

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