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CRINOIDS OF THE FRANCIS SHALE
(MISSOURIAN) OF OKLAHOMA

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INTRODUCTION

The first crinoid to be reported from the Francis Shale, Upper Pennsylvanian (Kansas City, Missourian), in Oklahoma, was *Oklahomacrinus loeblichii* MOORE, 1939. While a student at the University of Oklahoma, RICHARD ALEXANDER explored the possibility of collecting more specimens at the brick pit just south of Ada, Pontotoc County, Oklahoma, and was joined by ALLEN GRAFFHAM and one of us (STRIMPLE) in excavating a large colony or pocket of crinoids. A few rather large concretions are associated with the zone and coal film occurs on some bedding planes containing the crinoids. GRAFFHAM found some small crinoid colonies made up exclusively of *Exocrinus*. STRIMPLE (1952) reported three species of *Texacrinus* as *T. interruptus* STRIMPLE, *T. irradiatus* STRIMPLE, and *T. compactus* STRIMPLE, and in 1954, *Plummericrinus striatus* STRIMPLE. The presently considered collection represents some of the better-preserved or rare specimens held by ALLEN GRAFFHAM for many years in his private collection but subsequently pur-

chased and repositated at the University of Oklahoma. We are deeply obligated to Dr. CARL C. BRANSON, former Director of the Oklahoma Geological Survey, for allowing us to study the material.

Additional species reported here are *Laudonocrinus* sp. cf. *L. subsinuatus* (MILLER & GURLEY), *Oklahomacrinus loeblichii variabilis* STRIMPLE & MOORE, n. subsp., *Chlidonocrinus ornatus* STRIMPLE & MOORE, n. sp., *C.(?)* sp., *Aesiocrinus magnificus* MILLER & GURLEY, *A. francisensis* STRIMPLE & MOORE, n. sp., *Halogetocrinus? tumidus* STRIMPLE & MOORE, n. sp., *Stellarocrinus* sp. cf. *S. exsculptus* STRIMPLE, *Brabeocrinus* sp., *Galateacrinus ornatus* MOORE, *Exocrinus* sp. cf. *E. multirami* STRIMPLE, *Elibatocrinus* sp. cf. *E. leptocalyx* MOORE, *Graffhamicrinus* sp. cf. *G. graphicus* (MOORE & PLUMMER), *Exoriocrinus rugosus* STRIMPLE & MOORE, n. sp., *Glaukocrinus planus* STRIMPLE & MOORE, n. sp., *Apo-graphiocrinus* sp. cf. *A. facetus* MOORE & PLUMMER, and *Parethelocrinus* sp.

SYSTEMATIC DESCRIPTIONS

Family AMPELOCRINIDAE Kirk, 1942

Subfamily AMPELOCRININAE Kirk,
1942

Genus CHLIDONOCRINUS Strimple &
Watkins, 1969

TYPE-SPECIES.—*Chlidonocrinus echinatus* STRIMPLE & WATKINS, 1969, p. 189.

DIAGNOSIS.—Dorsal cup truncate cone- or bowl-shaped; anal plate large, not extending ap-

preciably above summit of cup, faceted for two equidimensional tube plates; primibrach 1 low, primibrach 2 axillary, short; column large, pentalobate, bearing long cirri in proximal region, lumen pentagonal in outline.

SPECIES.—*Chlidonocrinus echinatus* STRIMPLE & WATKINS, 1969, Marble Falls Formation (Atokan), Texas; *C. trinodus* STRIMPLE & WATKINS, 1969, Fayetteville Formation (Chesteran), Oklahoma; *C. erectus* STRIMPLE & MOORE, 1971, Bond Formation (Missourian), Illinois; *C. ornatus*

STRIMPLE & MOORE, n. sp., *C. planatus* STRIMPLE & MOORE, n. sp., Francis Shale (Missourian), Oklahoma.

DISCUSSION.—This genus was assigned to the Cymbiocrinidae by STRIMPLE & WATKINS, 1969, because the base of cup was thought to be invaginated. *Chlidonocrinus erectus* was found to have a subhorizontal base with distal tips of infrabasals upflared and visible in side view of cup and the genus was removed to the family Ampelocrinidae. *C. ornatus* has a subhorizontal base with the infrabasals mildly upflared.

OCCURRENCE.—Mississippian (Chesteran)-Pennsylvanian (Atokan-Missourian); USA (Oklahoma-Texas-Illinois).

CHLIDONOCRINUS ORNATUS Strimple & Moore,
n. sp.

Figures 1, 3; 2, 4; 3, 1; 4, 1

DESCRIPTION.—This species is represented in the collections by three partial crowns. The arms are indifferently preserved but syzygial pairs of brachials with gaped sutures are observed. Brachials are decorated with longitudinal striae. One paratype (OU6070) appears to have most of the anal tube preserved. The plates of the tube are irregular as to size and shape but are mostly large and tumid. Displaced plates show pore-slits along the lateral sides.

The dorsal cup is large, bowl-shaped, with broad, low ridges passing from plate to plate, areas at the meeting of plate angles being deeply impressed. The entire surface of the calyx is decidedly granular in appearance. Basals moderately large, hexagonal (except posterior which is broadly truncated for reception of single anal plate); radials larger than basals, pentagonal, with articular facets sloping inward; they are short but fill width of the plates, outer ligament furrow well-defined, near edge of cup periphery. Anal plate about 0.7 size of adjacent radials, not extended appreciably above summit of cup, with very low facets for reception of 2 tube plates. Column large, pentastellate.

Measurements of Holotype in Millimeters

Width of dorsal cup (distorted)	20.0
Diameter of infrabasal circlet	7.8
Width and length of basal plate ..	7.0, 7.0
Width and length of radial plate ..	8.6, 6.3
Width and length of anal plate	6.7, 5.0

TYPES.—Holotype, OU5799, paratypes OU6070C, OU6064, collected by ALLEN GRAFFHAM.

OCCURRENCE.—Francis Shale, Pennsylvanian (Missourian); brick pit at southeast edge of Ada, Pontotoc County, Oklahoma.

Genus HALOGETOCRINUS Strimple &
Moore, 1971

TYPE-SPECIES.—*Aesiocrinus paucus* STRIMPLE, 1951, p. 22.

DIAGNOSIS.—Cup low, saucer-shaped; five infrabasals subhorizontal in attitude, not visible from side; five basals usually small; five radials large, width and length about equal, with articular facets filling their upper face; one large anal (radial) in line with radials, in oblique contact with posterior basal, followed evenly above by two plates; brachials cuneiform above first branching, may be syzygial; armlets nonpinnulate, composed of rectilinear brachials, first branching on primibrach 3; stem round or subpentagonal, very cirriferous.

SPECIES.—*Aesiocrinus paucus* STRIMPLE, 1951, p. 22, *A. prudentia* STRIMPLE, 1963, p. 72, *Lecobasicrinus subidus* STRIMPLE & WATKINS, 1969, p. 192, *Halogetocrinus? tumidus* STRIMPLE & MOORE, n. sp.

OCCURRENCE.—Pennsylvanian (Atokan-Virgilian); USA (Texas-Oklahoma-Kansas-Illinois).

HALOGETOCRINUS? TUMIDUS Strimple & Moore,
n. sp.

Figures 5, 1; 6, 1

DIAGNOSIS.—Dorsal cup with more erect sides and more tumid plates than in type-species; also lacking large armlets in proximal portion of arms.

DISCUSSION.—*Halogetocrinus? tumidus* represents a linkage between *Allosocrinus* STRIMPLE and *Halogetocrinus*. It is ascribed to *Halogetocrinus* because the dorsal cup is low, the column large, the proximal end of anal plate diagonal rather than horizontal, and the brachials typical of the genus. Maximum width of dorsal cup 8 mm, height 4 mm.

HOLOTYPE.—OU6163, collected by ALLEN GRAFFHAM.

OCCURRENCE.—Francis Shale, Pennsylvanian (Missourian); brick pit at southeast edge of Ada, Pontotoc County, Oklahoma.

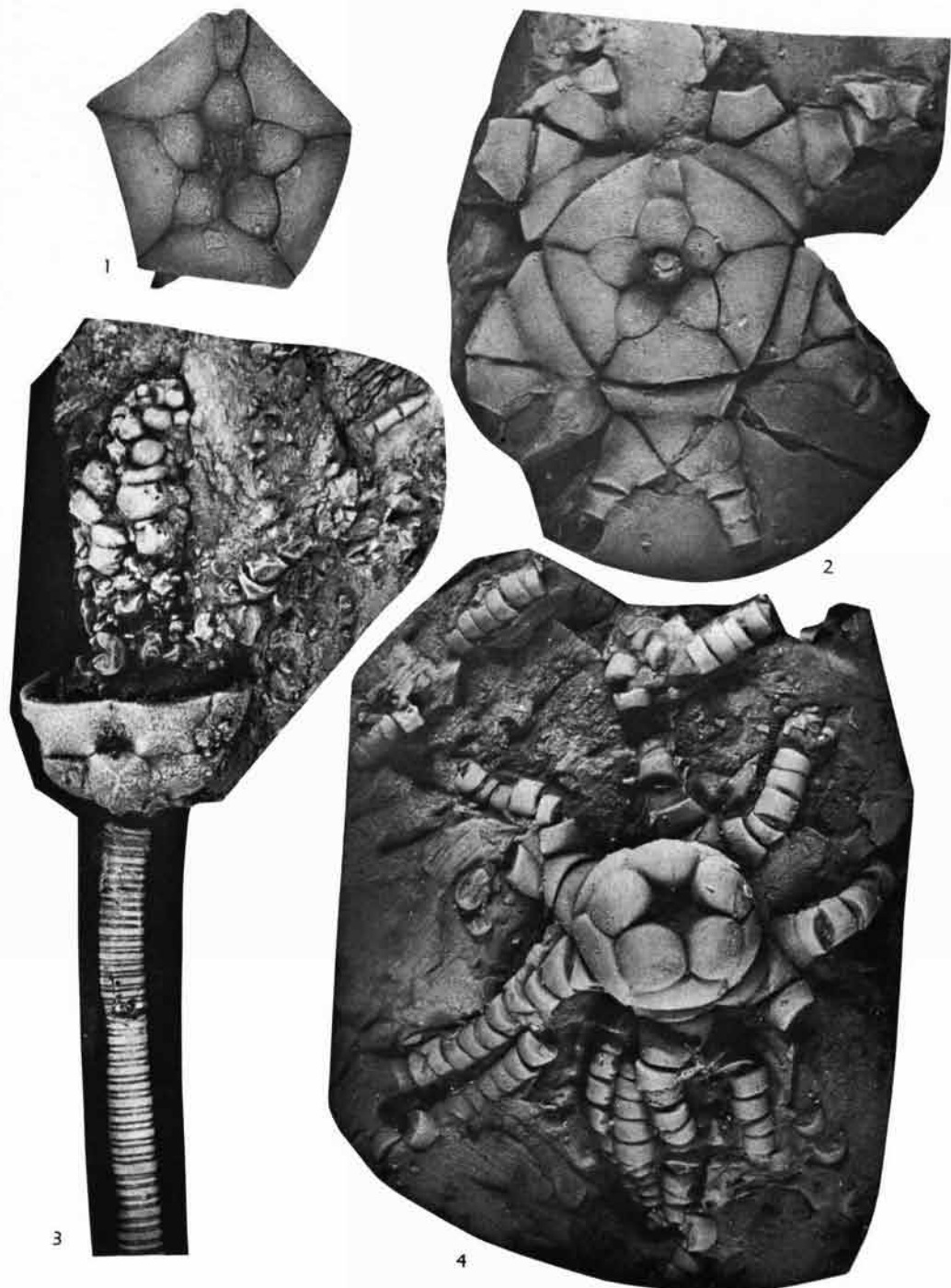


FIG. 1. *Oklahomacrinus*, *Chlidonocrinus*, and *Aesiocrinus* from Francis Shale, Upper Pennsylvanian, near Ada, Oklahoma.

1. *Oklahomacrinus loeblichii* MOORE, basal view of dorsal cup, hypotype (OU4997), $\times 2.2$.

2. *Oklahomacrinus loeblichii* MOORE, basal view of partial crown, hypotype (OU6071B), $\times 2.2$.

3. *Chlidonocrinus ornatus* STRIMPLE & MOORE, n. sp.,

side view of paratype (OU6070C), showing column and anal tube, $\times 1.6$.

4. *Aesiocrinus francisensis* STRIMPLE & MOORE, n. sp., basal view of holotype (OU4431) showing arms, $\times 2.2$.

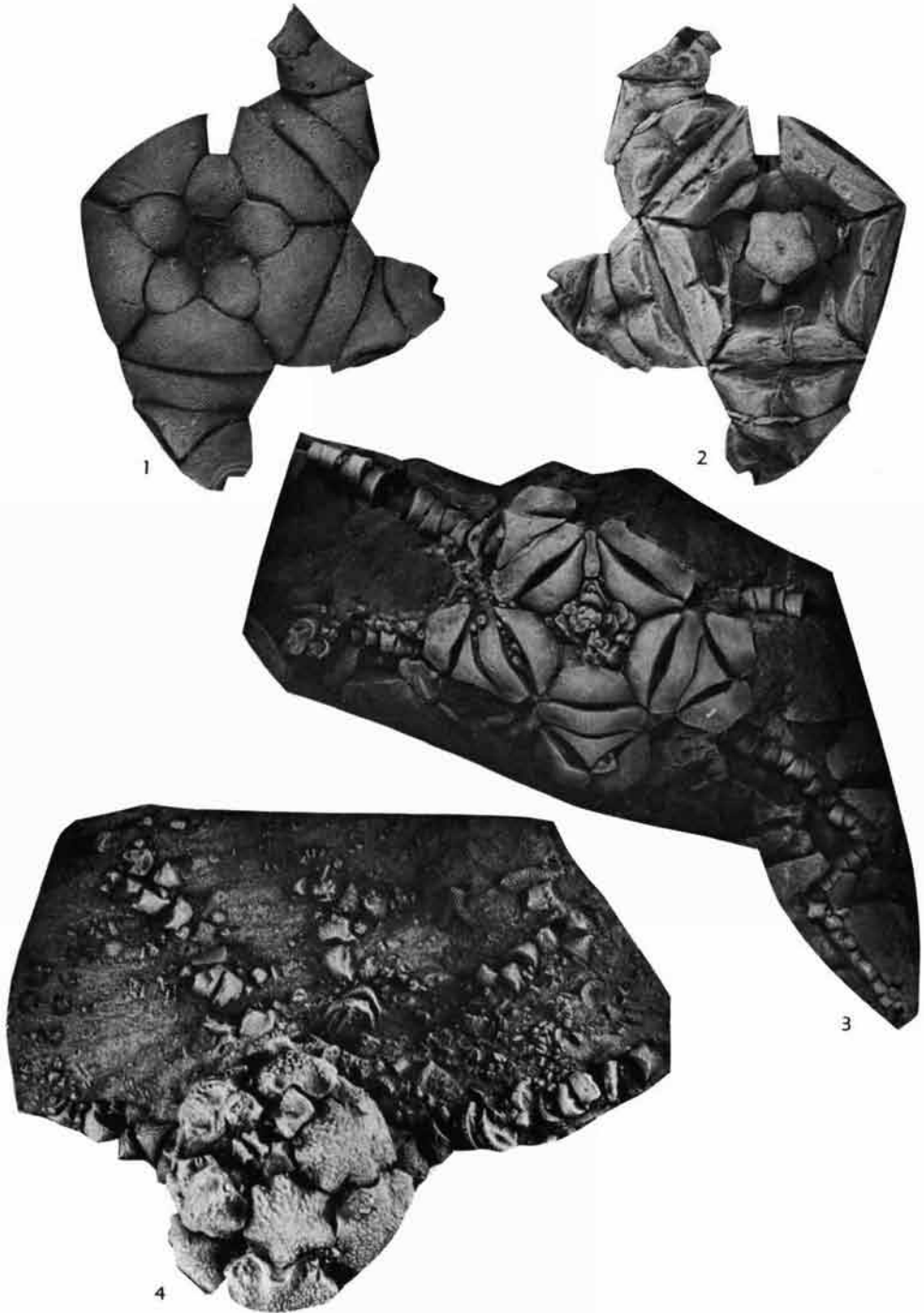


FIG. 2. *Oklahomacrinus* and *Chlidonocrinus* from Francis Shale, Upper Pennsylvanian, near Ada, Oklahoma.

- 1-2. *Oklahomacrinus loeblichii* MOORE. Hypotype (OU 6071A) viewed from base, summit, $\times 2.2$.
 3. *Oklahomacrinus loeblichii variabilis* STRIMPLE & MOORE, n. subsp. Holotype (OU47188) crown viewed

- from base, $\times 1.1$.
 4. *Chlidonocrinus ornatus* STRIMPLE & MOORE, n. sp. (OU6064), crown viewed from below, posterior interradius up, $\times 1.6$.

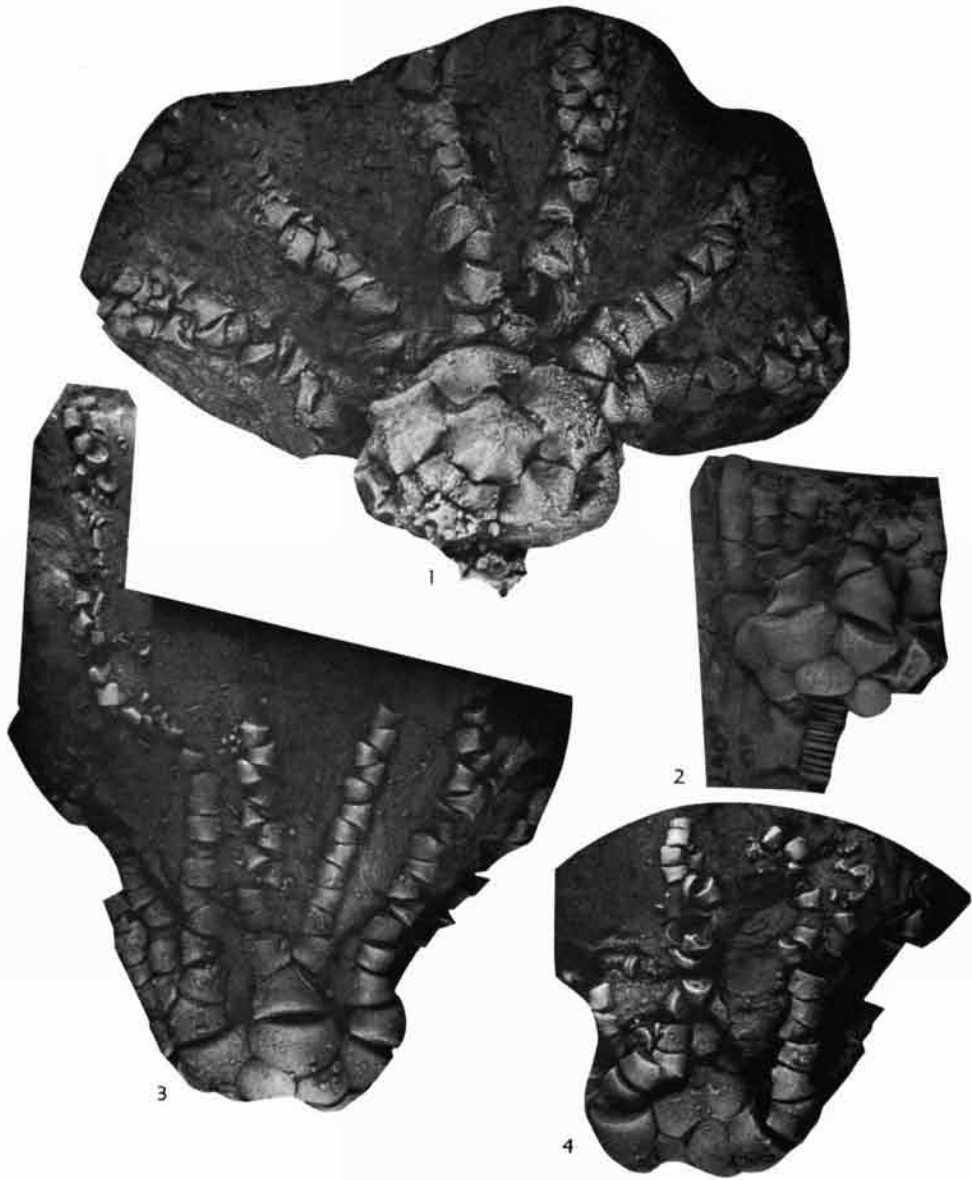


FIG. 3. *Chlidonocrinus* and *Plummericrinus* from the Francis Shale, Upper Pennsylvanian, near Ada, Oklahoma.

1. *Chlidonocrinus ornatus* STRIMPLE & MOORE, n. sp. (OU5779), oblique view of partial crown, $\times 1.6$.
 2-4. *Plummericrinus striatus* STRIMPLE.—2. Hypotype (OU6067), side view of partial crown, radial to

right displaced and showing ligament? furrows in suture faces, $\times 1.1$.—3, 4. Hypotype (OU6066), crown viewed from anterior and posterior, $\times 1.1$.

Family CYMBOCRINIDAE Stimpfle & Watkins, 1969

Genus AESIOCRINUS Miller & Gurley, 1890

TYPE-SPECIES.—*Aesiocrinus magnificus* MILLER & GURLEY, 1890.

DIAGNOSIS.—Crown very tall, arms 10, slender, pinnulate, not appressed. Cup low, bowl-shaped, base shallowly concave, one anal plate supporting two tube plates above, radial articular facets typically short. Two short primibrachs, secundibrachs equiuniserial. Anal tube very

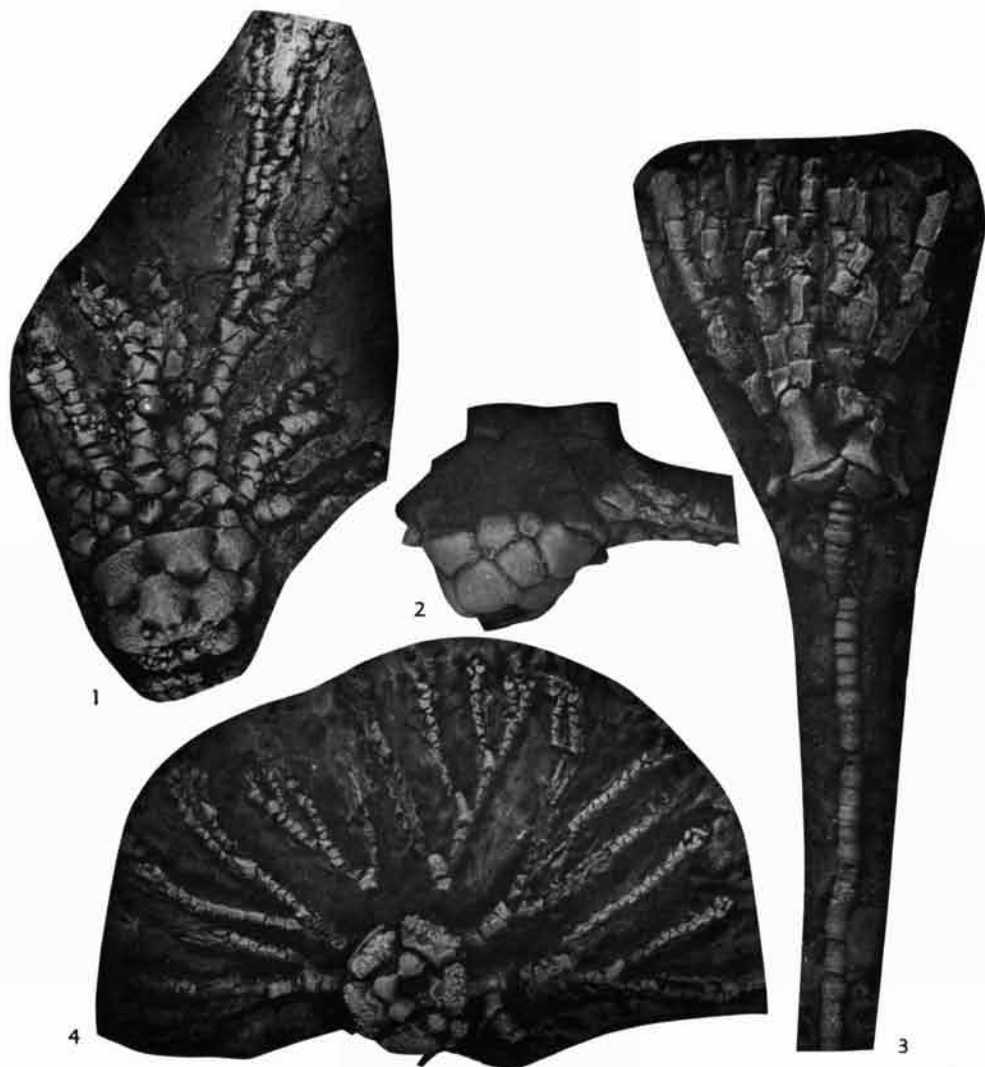


FIG. 4. *Chlidonocrinus*, *Plummericrinus*, *Exocrinus*, and *Galateacrinus* from Francis Shale, Upper Pennsylvanian, near Ada, Oklahoma.

1. *Chlidonocrinus ornatus* STRIMPLE & MOORE, n. sp. (OU5797), side view of crown, $\times 1.1$.
2. *Plummericrinus striatus* STRIMPLE. Hypotype (OU 5409A), posterior view of partial crown showing three anal plates in CD interray, $\times 1.6$.
3. *Exocrinus* sp. cf. *E. multirami* STRIMPLE. Hypotype (OU4487), side view of crown with stem attached, $\times 2.2$.
4. *Galateacrinus ornatus* MOORE. Hypotype (USNM S4905), basal view of crown with arms expanded, CD interray to lower right, $\times 1.6$.

long, slender, tapered, composed of six series of rugose plates. Stem pentagonal.

OCCURRENCE.—Pennsylvanian (Morrowan-Virgilian) to Lower Permian; USA.

AESIOCRINUS MAGNIFICUS Miller & Gurley, 1890

Figure 7, 5

DESCRIPTION.—A single dorsal cup with a portion of the arms preserved is conspecific with *Aesiocrinus magnificus*. Cup plates are smooth, sutures distinct but not impressed; single anal plate large, quadrangular, followed by 2 tube plates. Two low primibrachs, proximal secundi-brachs tapering rather quickly, thereafter, main-

taining stable width, evenly uniserial, pinnule-bearing on alternate sides. Proximal columnals subpentagonal. The dorsal cup is 16.3 mm wide, 5.0 mm high.

HYPOTYPE.—OU5676, collected by ALLEN GRAFFHAM.

OCCURRENCE.—Francis Shale, Pennsylvanian (Missourian); brick pit southeast edge of Ada, Oklahoma.

AESIOCRINUS FRANCISENSIS Strimple & Moore, n. sp.

Figure 1, 4

DESCRIPTION.—Dorsal cup medium bowl-shaped with impressed sutures and small, pronounced basal invagination; infrabasals confined to invagination, moderately downflared; basals large, broad, tumid; radials moderately large, tumid; single large anal plate resting evenly on CD basal, extending slightly above cup summit and faceted for 2 anal tube plates above. Arms 10, bifurcation on primibrach 2, uniserial, secundibrachs pinnulate on alternating sides; column subpentagonal. Dorsal cup is 11.7 mm wide, 4.5 mm high.

DISCUSSION.—The basal concavity in *Aesio-crinus francisensis* is more sharply defined, sutures more impressed and cup plates more tumid than observed in any other species of the genus.

HOLOTYPE.—OU4431, collected by ALLEN GRAFFHAM.

OCCURRENCE.—Francis Shale, Pennsylvanian (Missourian); brick pit at southeast edge of Ada, Pontotoc County, Oklahoma.

Genus OKLAHOMACRINUS Moore, 1939

TYPE-SPECIES.—*Oklahomacrinus supinus* MOORE, 1939, p. 258.

DIAGNOSIS.—Dorsal cup extremely depressed, consisting of straight-sided pentagon with hollowed base (exception, *Oklahomacrinus detrusus* [STRIMPLE, 1951], new combination, which has a relatively high cup). Infrabasals not visible in side view of cup, proximal portions subhorizontal, distal tips slightly downflared, internally may form a cone higher than the radials; basals may be protuberant, readily visible in side view, to concave with only some distal tips visible in side view; radials large with midportion tangent to basal plane, inner articular facet short; anal plate narrow, elongate, may extend slightly above cup summit, faceted for a single tube plate. Arms ten, uniserial, pinnulate on opposite sides of alternate brachials, primibrach 1 low, wide, filling upper facet of radial, juncture with distal edge of

radial usually slightly undulating, primibrach 2 axillary, triangular in outline with steeply directed distal facets. Proximal columnals pentagonal.

DISCUSSION.—In all specimens of *Oklahomacrinus* observed by us with primibrach 1 preserved, the juncture between radial and primibrach 1 is confined to the outer ligament area. The inner ligament areas are never found in full contact. When the two plates are not in solid contact externally the suture is strongly gaped, as exhibited in *O. loeblichii variabilis* described herein (Fig. 2, 3). It is thought by us that large muscles occupied the inner ligament area, allowing for considerable movement of the small, long arms but preventing them from ever remaining vertical. The arms were too small to have ever been tightly closed in a manner found in the majority of late Paleozoic crinoids (e.g., *erisocrinids*, *delocrinids*, etc.).

OCCURRENCE.—Pennsylvanian (Desmoinesian-Virgilian); USA.

OKLAHOMACRINUS LOEBLICHII Moore, 1939, p. 261

Figures 1, 1, 2; 2, 1, 2

DISCUSSION.—The holotype of this species is an incomplete crown with some disjointed plates. However, the restoration and interpretation by MOORE (1969, p. 261) is adequate and correct on the basis of the three well-preserved topotypes studied here. The dorsal cups of the topotypes are essentially undistorted and show the basals to be somewhat more prominent than demonstrated by the holotype. The proximal portions of the basals curve sharply into and form almost vertical sides of the basal invagination. Two of the specimens have substantial portions of the proximal arms attached and they are directed subhorizontally as noted by MOORE (*ibid.*, p. 256).

TOPOYPES.—OU6071A, OU6071B, OU4997, collected by ALLEN GRAFFHAM.

OCCURRENCE.—Francis Shale, Pennsylvanian (Missourian); brick pit at southeast edge of Ada, Pontotoc County, Oklahoma.

OKLAHOMACRINUS LOEBLICHII VARIABILIS

Strimple & Moore, n. subsp.

Figure 2, 3

DESCRIPTION.—One specimen including substantial portions of the arms is considered to be a

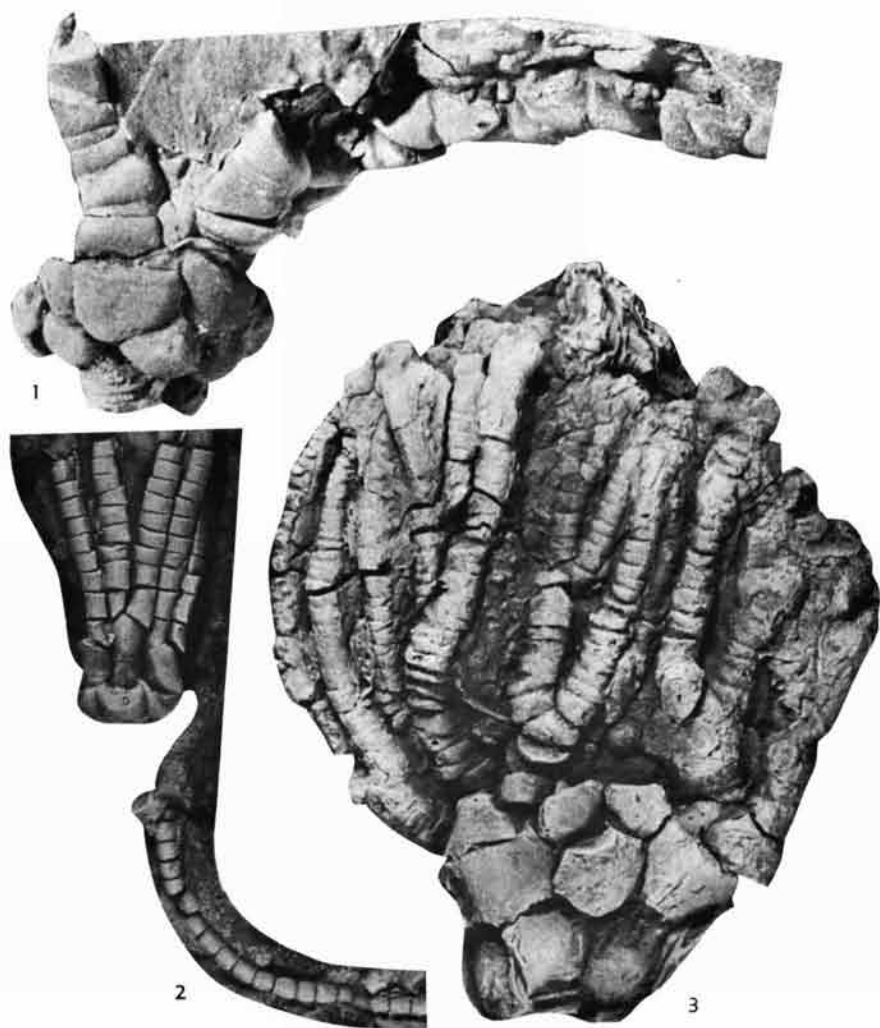


FIG. 5. *Halogetocrinus*, *Apographiocrinus*, and *Texacrinus* from Francis Shale, Upper Pennsylvanian, near Ada, Oklahoma.

1. *Halogetocrinus?* *tumidus* STRIMPLE & MOORE, n. sp. Holotype (OU6163), C ray view of crown, $\times 3$.
2. *Apographiocrinus* sp. cf. *A. jacetus* MOORE & PLUMMER. Hypotype (OU5408), E ray view of crown with appreciable portion of stem preserved, $\times 2.2$.
3. *Texacrinus irradiatus* STRIMPLE. Hypotype (OU6167), posterior (CD interray) view of large crown, $\times 1.6$.

subspecies of *O. loeblichii* because of its more impressed sutures, smaller and less projected basals, and a slender, peculiarly shaped anal plate. The anal plate is sharply constricted near the perimeter of the cup, thereafter retaining a uniform width to its termination. The dorsal cup has a maximum width of 22.5 mm.

HOLOTYPE.—OU4788, collected by ALLEN GRAFFHAM.
 OCCURRENCE.—Francis Shale, Pennsylvanian (Missourian); brick pit in southeast edge of Ada, Oklahoma.

Family STELLAROCRINIDAE Strimple, 1961

Genus STELLAROCRINUS Strimple, 1940

TYPE-SPECIES.—*Cyathocrinus stillativus* WHITE, 1879, p. 258.

DESCRIPTION.—Cup medium bowl-shaped with basal concavity; infrabasals subhorizontal; basals large, usually protruded about basal invagination; radials wider than long, with articular

facets typically not as wide as radials; three anal plates in *CD* interray, advanced arrangement with one plate (radial) followed above by two equidimensional plates. Arms wide, flattened exteriors, biserial, not opposed, two or more bifurcations, primibrach *I* axillary, stout pinules. Anal tube long, composed of alternating series of thick tube plates, respiratory slits present, anus at termination of tube, covered by small plates, column round.

OCCURRENCE.—Pennsylvanian (Desmoinesian)-Lower Permian; USA.

STELLAROCRINUS sp. cf. **S. EXSCULPTUS**

Strimple, 1940

Figure 7, 1-3, 6

A single dorsal cup in the collection with primaxils attached is closely related to *Stellarocrinus exsculptus* STRIMPLE, 1940, from the Wann Formation, Ochelata Group, Missourian, of northeastern Oklahoma.

FIGURED SPECIMEN.—OU5800, collected by ALLEN GRAFFHAM.

OCCURRENCE.—Francis Shale, Pennsylvanian (Missourian); brick pit at southeast edge of Ada, Pontotoc County, Oklahoma.

Family PACHYLOCRINIDAE Kirk, 1942

Genus PLUMMERICRINUS Moore & Laudon, 1943

TYPE-SPECIES.—*Pachylocrinus mcquirei* MOORE, 1939.

DIAGNOSIS.—Crown slender; cup truncate bowl-shaped, base concave; infrabasals five, not visible from side, mostly concealed by stem; basals five, proximal part sloping downward, distal part upward, reaching midheight of cup; radials five, projecting outward so as to make interradyal notches, facets equal to full width of radials but not laterally in contact, bearing transverse ridge facets equal to full width of plates but not laterally in contact, bearing transverse ridge and ligament pits; three anals in cup, anal sac tubular, curved forward, side plates plicated; arms uniserial, branching isotomously on first primibrach and higher, pinnulate.

OCCURRENCE.—Pennsylvanian (Morrowan-Virgilian); USA.

PLUMMERICRINUS STRIATUS Strimple, 1954

Figures 3, 2-4; 4, 2; 8, 2

DISCUSSION.—The species *Plummericrinus*

striatus STRIMPLE, 1954, p. 204, has been adequately documented. Several crowns in the present collection do not add any information except that one (topotype OU5407) has very long arms preserved to their termination and thus provides data relative to the proportionate length of arms to crown length (99%), as well as to establish a maximum number of arms at 20. The second isotomous bifurcation of arms in the complete specimen takes place on secundibrach 9-16.

TOPOYPES.—OU6066, OU6067, OU5407, collected by ALLEN GRAFFHAM.

OCCURRENCE.—Francis Shale, Pennsylvanian (Missourian); brick pit at southeast edge of Ada, Pontotoc County, Oklahoma.

Genus GALATEACRINUS Moore, 1940

TYPE-SPECIES.—*Galateacrinus stevensi* MOORE, 1940, p. 46.

DESCRIPTION.—Dorsal cup discoid, the circlet of radials projecting laterally very prominently and rather sharply separated from the basals; base gently concave; infrabasals five, relatively small, flaring gently downward, not visible in side view of the cup; basals five, subequal, somewhat bulbous, clearly visible in side view of the cup, tangent to basal plane of cup at about their midlength; radials five, extremely convex in longitudinal profile, their proximal and distal areas nearly horizontal, with intervening area produced laterally as a flange; articular facets subhorizontal, short, distinctly narrower than greatest width of radials, but with ends of neighboring transverse ridges almost touching. Three anal plates in the cup. First primibrachs axillary in at least three of the rays. Stem round.

OCCURRENCE.—Pennsylvanian (Desmoinesian-Virgilian); USA (Kansas-Oklahoma-Texas-Illinois).

GALATEACRINUS ORNATUS Moore, 1940

Figure 4, 4

DISCUSSION.—This species was described from a single incomplete dorsal cup from the lower part of the Coffeyville Shale, Ochelata Group, Missourian, near Coffeyville, Kansas. Arm structure for the genus has been reported by STRIMPLE & MOORE, 1971, p. 18, for *G. coacervatus* from the LaSalle Limestone, Bond formation, Missourian, south of Pontiac, Livingston County, Illinois. About 30 endotomous arms are indicated. A single specimen (S4905) in the Springer Collec-

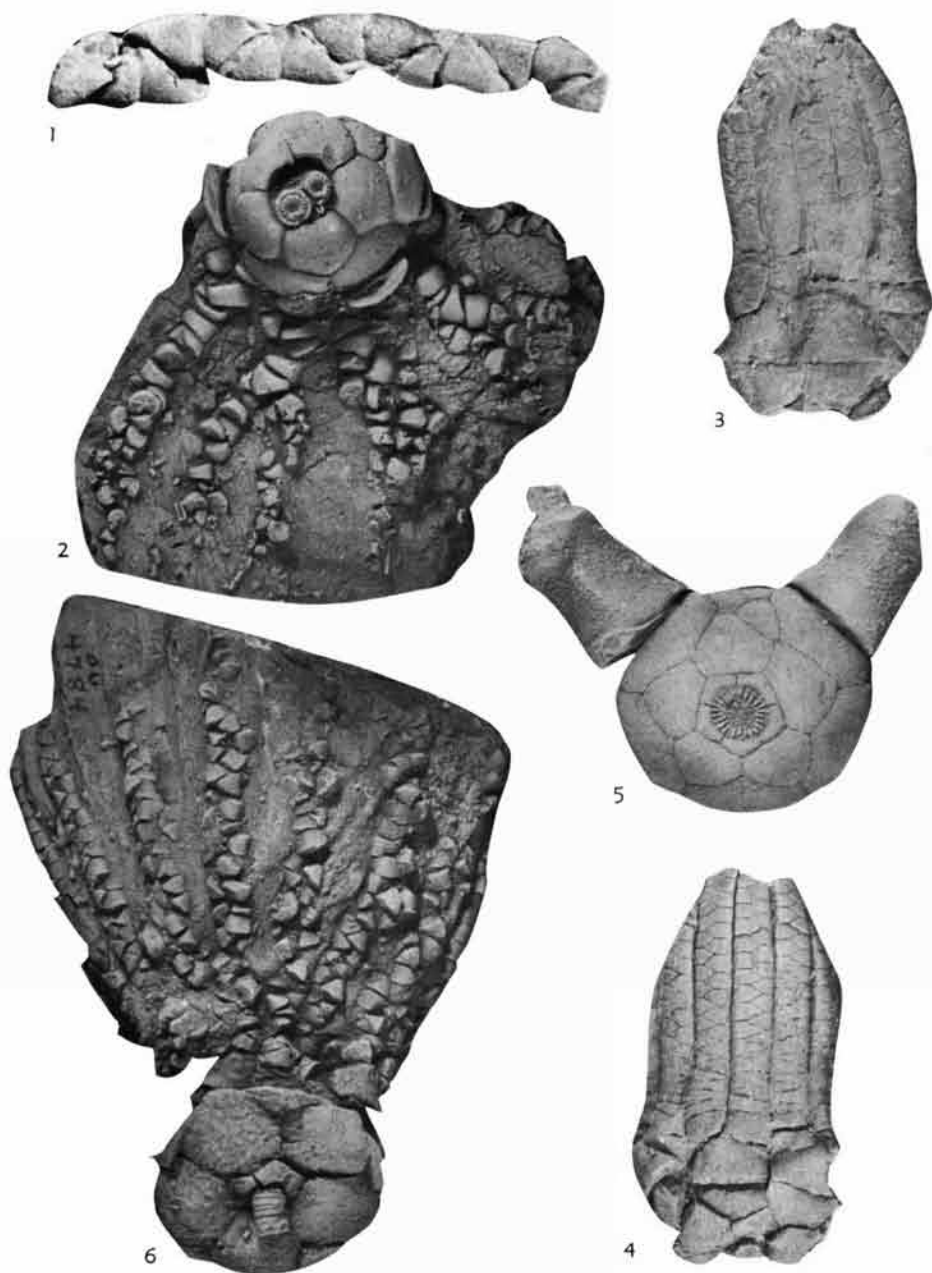


FIG. 6. *Halogetocrinus*, *Texacrinus*, *Graffhamicrinus*, *Laudonocrinus*, and *Parethelocrinus* from Francis Shale, Upper Pennsylvanian, near Ada, Oklahoma.

1. *Halogetocrinus?* *timidus* STRIMPLE & MOORE, n. sp. Portion of arm of holotype (OU6163) showing paired, wedgelike brachials, $\times 3.2$.
2. *Texacrinus* *irradiatus* STRIMPLE. Hypotype (OU 5409A), crown viewed from base, $\times 1.6$.
- 3, 4. *Graffhamicrinus* sp. cf. *G. graphicus* MOORE & PLUMMER. Hypotype (OU5680), crown viewed from side and opposite side, $\times 1.1$.
5. *Laudonocrinus* sp. cf. *L. subsinuatus* (MILLER & GURLEY). Hypotype (OU6068B), dorsal cup with two primibrachia 1 preserved viewed from base, $\times 2.9$.
6. *Parethelocrinus* sp. Figured specimen (OU4784), oblique view of crushed crown, $\times 1.1$.

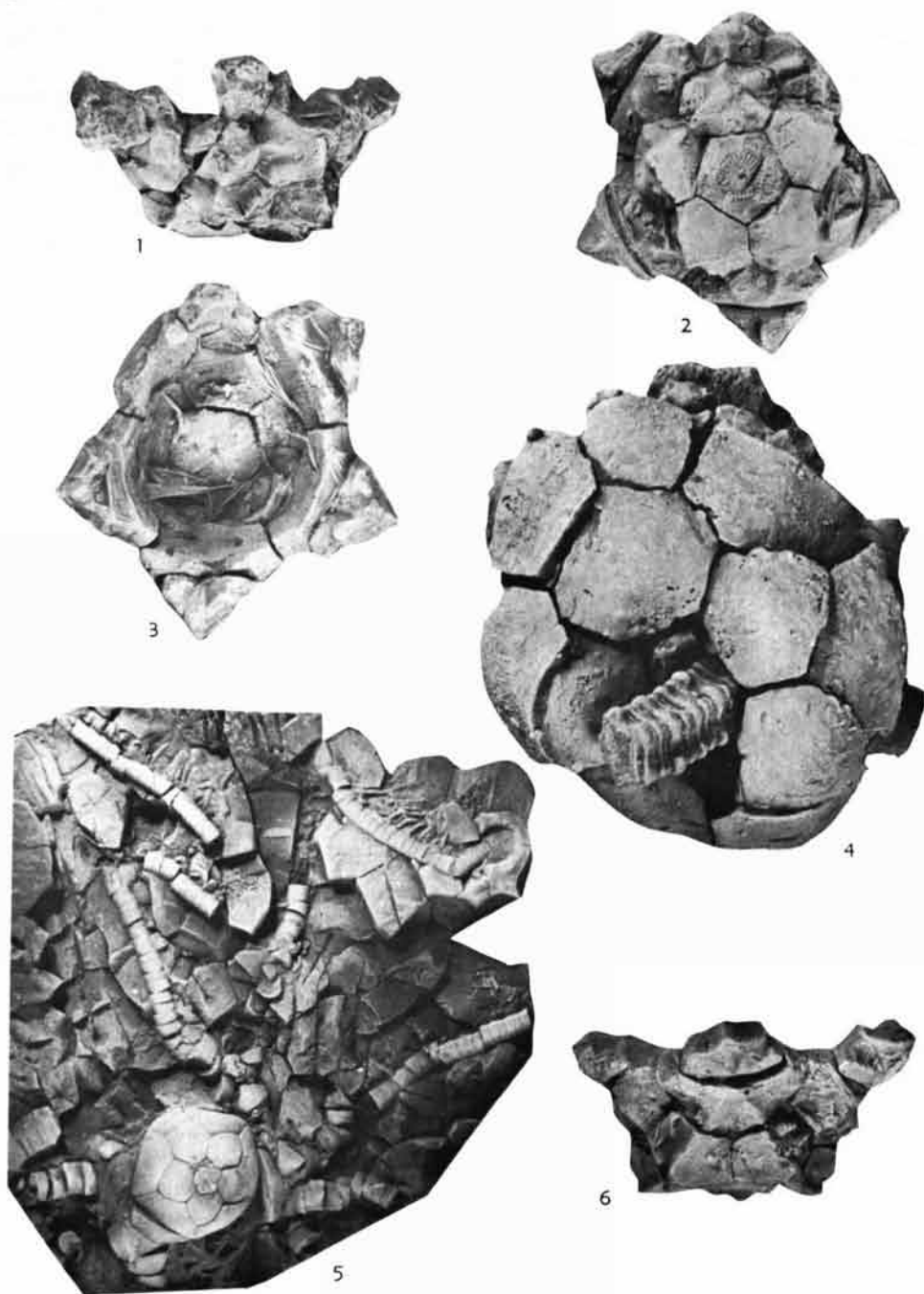


FIG. 7. *Stellarocrinus*, *Chlidonocrinus?*, and *Aesiocrinus* from Francis Shale, Upper Pennsylvanian, near Ada, Oklahoma.

1-3. *Stellarocrinus* sp. cf. *S. exsculptus* STRIMPLE. Hypotype (OU5800) viewed from posterior, base and summit, $\times 2.2$.

4. *Chlidonocrinus?* sp. (OU6073B), viewed obliquely from below, $\times 2.2$.

5. *Aesiocrinus magnificus* MILLER & GURLEY. Hypotype (OU5676), dorsal cup with portions of arms preserved viewed from below (note delicate pinnules in upper left), $\times 1.1$.

6. *Stellarocrinus* sp. cf. *S. exsculptus* STRIMPLE. Hypotype (OU5800) viewed from anterior, $\times 2.2$.

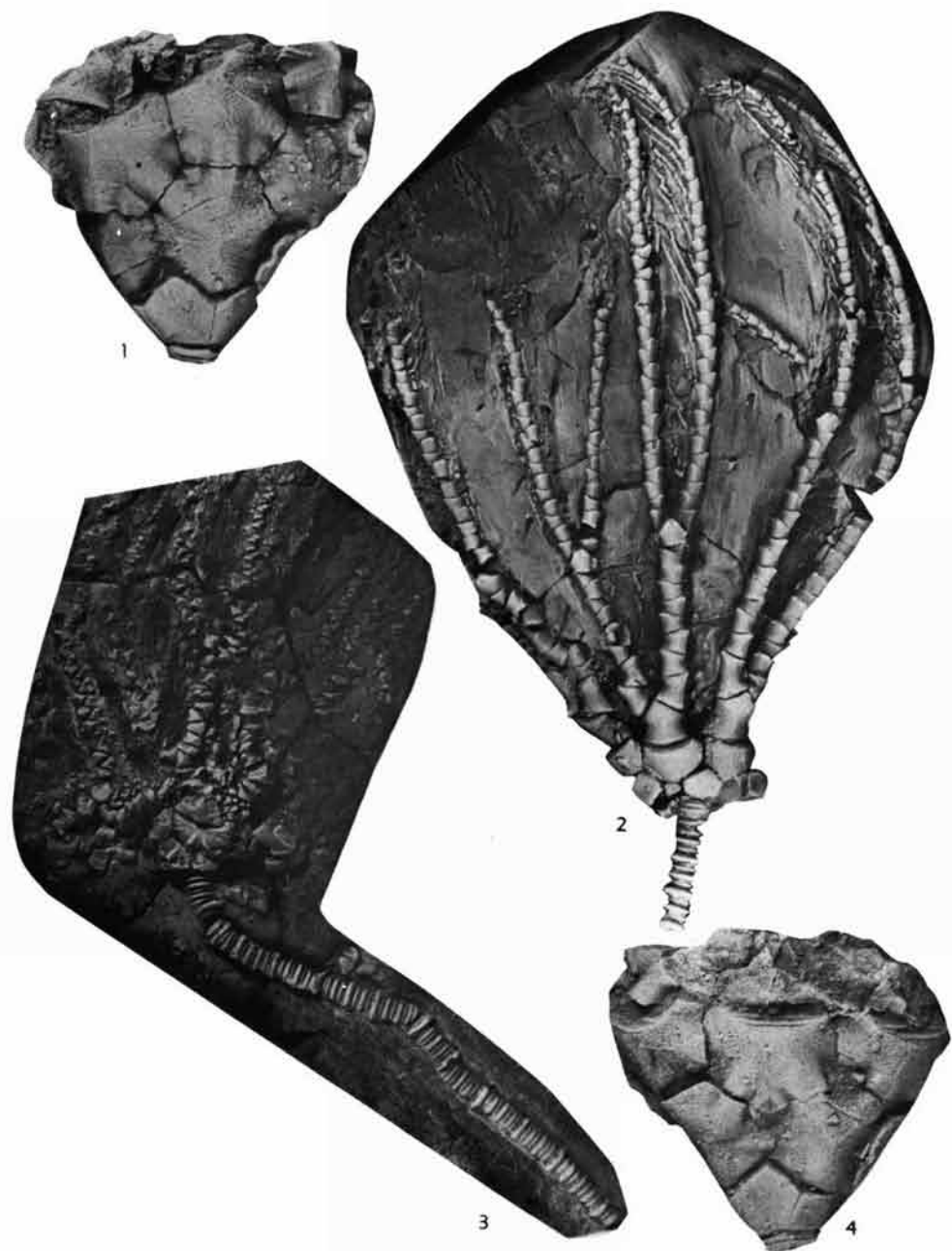


FIG. 8. *Exoriocrinus*, *Plummericrinus*, and *Brabeocrinus* from the Francis Shale, Upper Pennsylvanian, near Ada, Oklahoma.

1. *Exoriocrinus rugosus* STRIMPLE & MOORE, n. sp. Paratype (OU6070), anterior view of aberrant dorsal cup, $\times 2.2$.
2. *Plummericrinus striatus* STRIMPLE. Hypotype (OU 5407), a complete crown in side view, $\times 1.1$.
3. *Brabeocrinus* sp. Figured crown (OU5675) in side view, $\times 1.1$.
4. *Exoriocrinus rugosus* STRIMPLE & MOORE, n. sp. Paratype (OU6070), posterior view of aberrant specimen, $\times 2.2$.

tion, U.S. National Museum, from the Francis Shale has most of the arms attached. The arms of *G. ornatus* are more numerous and thinner than those of *G. coacervatus*. At least 40 arms are present and as many as 60 may be developed. Distal axillaries are projected and have a spatulate appearance. Normal brachials are uniform, keeled, with points on alternate sides coinciding with the position of the pinnule. Three anal plates are present in the *CD* interray with radial in dominant posterior position.

HYPOTYPE.—Springer Collection (S4905), U.S. National Museum, collected by ALLEN GRAFFHAM.

OCCURRENCE.—Francis Shale, Pennsylvanian (Missourian); brick pit at southeast edge of Ada, Pontotoc County, Oklahoma.

Family DECAOCRINIDAE Bather, 1893

Genus GLAUKOSOCRINUS Strimple, 1962

TYPE-SPECIES.—*Malaioocrinus parviusculus* MOORE & PLUMMER, 1940, p. 100.

DIAGNOSIS.—Dorsal cup low, truncate bowl-shaped with evenly rounded sides and a small basal concavity. Three anal plates in posterior interradius, short radial articular facets, small round stem.

DISCUSSION.—In the "Discussion" section of the original description of *M. parviusculus*, MOORE & PLUMMER (*ibid.*, p. 101), gave substantial evidence to substantiate the removal of the species from typical *Malaioocrinus* (e.g., shorter radial articular facets, smaller stem and other unstated features).

OCCURRENCE.—Pennsylvanian (Desmoinesian-Missourian); USA.

GLAUKOSOCRINUS PLANUS Strimple & Moore, n. sp. Figure 9, 1

DESCRIPTION.—Posterior interradius unusually broad for the genus. Primaxils of arms are equidimensional, narrowing slightly above radial facet and terminating distally in broad tip flanked by long, steeply inclined facets for articulation with secundibrachs which extend almost straight outward. Other axillary plates short, with blunt distal projection arranged in zigzag pattern. Free armlets not preserved except on proximal segments.

DISCUSSION.—The anal plate of *Malaioocrinus*

parviusculus extends very slightly above the cup summit, if at all, but is well above in *Glaukosoocrinus planus* and cup plates of the latter are more tumid than in the former species.

Measurements of Holotype in Millimeters

Length of arms (incomplete)	66.0
Height of cup (distorted)	10.5
Width of cup (distorted)	23.0
Width of infrabasal circle	4.0
Width and length of <i>D-E</i> basal	7.0, 6.9
Width and length of <i>A</i> radial	10.2, 5.5
Width of proximal columnals	2.8

HOLOTYPE.—OU6065, collected by ALLEN GRAFFHAM.

OCCURRENCE.—Francis Shale, Pennsylvanian (Missourian); brick pit at southeast edge of Ada, Pontotoc County, Oklahoma.

Family EXOCRINIDAE Strimple & Watkins, 1969

Genus EXOCRINUS Strimple, 1949

TYPE-SPECIES.—*Exocrinus multirami* STRIMPLE, 1949, p. 10.

DIAGNOSIS.—Dorsal cup low, truncate cone-shaped, with small but sharply defined basal concavity. Infrabasals small, subhorizontal, obscured by relatively large columnals; basals of medium size, extending well out of basal concavity; radials very large, almost twice as wide as long, lacking appreciable curvature either longitudinally or transversely, articular facets short; three anal plates in cup, radial in direct posterior position followed equally above by anal *X* and right tube plate, the latter elements having confluent distal facets. Arms 30, keeled, branching twice isotomously, the third time only in inner rays; primibrach *I* axillary in all rays. Distal axillaries may be elongated through fusion of brachials so that as many as three pinnules are present (two widely separated on one side and one at half length of plate on opposite side). Column large, round, alternatingly expanded columnals.

OCCURRENCE.—Pennsylvanian (Desmoinesian-Virgilian); USA.

EXOCRINUS sp. cf. *E. MULTIRAMI* Strimple, 1949

Figures 4, 3; 9, 2

DISCUSSION.—Five crowns in good to indifferent preservation are present in the collection. Hypotype (OU6164) is the best preserved and discloses *A*, *C* and *D* primibrachs *I* are decidedly



FIG. 9. *Glaukosocrinus* and *Exocrinus* from Francis Shale, Upper Pennsylvanian, near Ada, Oklahoma.

1. *Glaukosocrinus planus* STRIMPLE & MOORE, n. sp. Holotype (OU6065), diagonal CD view of crown, $\times 1.1$.
 2. *Exocrinus* sp. cf. *E. multirami* STRIMPLE. Hypotype (OU6164), basal view of crown, $\times 2.2$.

elongated; second branching on secundibrach 3 in all rays except the outer half-ray of C arm wherein secundibrach 2 is axillary; axillary secundibrachs are elongated and hyperpinnulated; tertibrach 3 or 4 usually axillary in inner rays only.

HYPOTYPES.—OU6069a, b, c, OU4787 (2 specimens), OU6164, OU4487, OU4786, collected by ALLEN GRAFFHAM.

OCCURRENCE.—Francis Shale, Pennsylvanian (Mis-

sourian); brick pit at southeast edge of Ada, Pontotoc County, Oklahoma.

Family POTERIOCRINITIDAE Bassler, 1938

Genus ELIBATOCRINUS Moore, 1940

TYPE-SPECIES.—*Elibatocrinus leptocalyx* MOORE, 1940, p. 36.

DIAGNOSIS.—Crown tall, expanded. Dorsal

cup steeply conical; three infrabasals, thickened internally, juncture with stem usually firm; five radials with short facets and straight transverse ridges are narrower than greatest width of plate; three anal plates in normal position. Arms slender, usually ten, uniserial, pinnulate, may branch on primibrach 1 or 2 but in one species, *E. elongatus* WEBSTER & LANE, 1966, are reported to branch again. Proximal columnals short and usually (exception, *E. concinnulus* MOORE, 1940) taper rapidly for a short distance.

DISCUSSION.—Considering the delicate nature of the cup plates and arms of this genus, it is remarkable that as many specimens have been preserved as are now known. Twenty-three specimens of infrabasal cones and cups were reported by MOORE (1940) from the Missourian and Virgilian. Three specimens of *Elibatocrinus elegans* STRIMPLE & MOORE, 1971, from the Missourian have been reported and at least that many more have subsequently been recovered. One specimen of *E. hoodi* STRIMPLE, 1961, is reported from the Desmoinesian and one specimen of *E. elongatus* WEBSTER & LANE, 1966, from the Lower Permian. Fusion of primibrachs 1 and 2 has taken place in *E. hoodi* and *E. elongatus* but the elements are decidedly separate in *E. elegans* as well as in a specimen from the Francis Shale (Missourian) described herein as *Elibatocrinus* sp. cf. *E. leptocalyx*.

OCCURRENCE.—Pennsylvanian (Desmoinesian)-Lower Permian; USA.

ELIBATOCRINUS sp. cf. **E. LEPTOCALYX** Moore, 1940
Figure 10, 1

DISCUSSION.—A single well-preserved dorsal cup with a few segments of nonaxillary primibrachs and a section of attached rapidly tapered columnals is represented in the collection and is ascribed to *Elibatocrinus* sp. cf. *E. leptocalyx*. The infrabasals and radials are proportionately somewhat longer and the basals somewhat shorter than found in the holotype of *E. leptocalyx*. Additional material is desirable before the full relationship is understood.

FIGURED SPECIMEN.—OU6165, collected by ALLEN GRAFFHAM.

OCCURRENCE.—Francis Shale, Pennsylvanian (Missourian); brick pit at southeast edge of Ada, Pontotoc County, Oklahoma.

Family DIPHUICRINIDAE Strimple & Knapp, 1966

Genus GRAFFHAMICRINUS Strimple, 1961

TYPE-SPECIES.—*Graffhamicrinus acutus* STRIMPLE, 1961, p. 124.

DIAGNOSIS.—Dorsal cup low, truncate bowl-shaped, with deep basal concavity; entire surface of cup and lower part of arms ornamented with pustules, nodes, tubercles, ridges or strong granules, or a combination of any; infrabasals down-flared; anal X plate hexagonal, extending vertically well above cup summit, faceted for single tube plate; arms ten, biserial except proximal-most secundibrachs, primibrachs 1 axillary, may be mildly protruded at apex but not appreciably protruded as a spine; column round, small.

DISCUSSION.—Typical specimens of *Delocrinus* have low, truncate bowl-shaped dorsal cups with deep basal concavity, smooth cup and arm surfaces, axillary primibrach 1 protruded into pronounced spine. Some Lower Permian and Upper Pennsylvanian species of *Delocrinus* have nonspinose primibrach 1 (e.g., *D. abruptus* MOORE & PLUMMER, 1940, p. 289, from the Beattie Limestone, Lower Permian, Kansas) demonstrating evolution from the spinose to nonspinose. All known ornate forms (*Graffhamicrinus*) have nonspinose primibrach 1.

KNAPP (1969) has suggested modification of *Graffhamicrinus* to include unornamented forms and has attempted to establish a system of phyletic lineages strictly on characters of the dorsal cup which he considered to be only valid generic criteria. We agree that ornamentation in itself may or may not be a consistent character but is a consistent feature and until a more refined taxonomic system is proposed (based on all known factors) the genus *Graffhamicrinus* is retained in its original concept.

OCCURRENCE.—Pennsylvanian (Desmoinesian-Virgilian) to Lower Permian; USA.

GRAFFHAMICRINUS sp. cf. **G. GRAPHICUS** (Moore & Plummer), 1940

Figure 6, 3, 4

DESCRIPTION.—A crown in relatively good preservation but with disturbed cup plates appears to be more closely related to *Graffhamicrinus graphicus* from the Graford Formation, Canyon Group (Missourian) of Texas, than to other

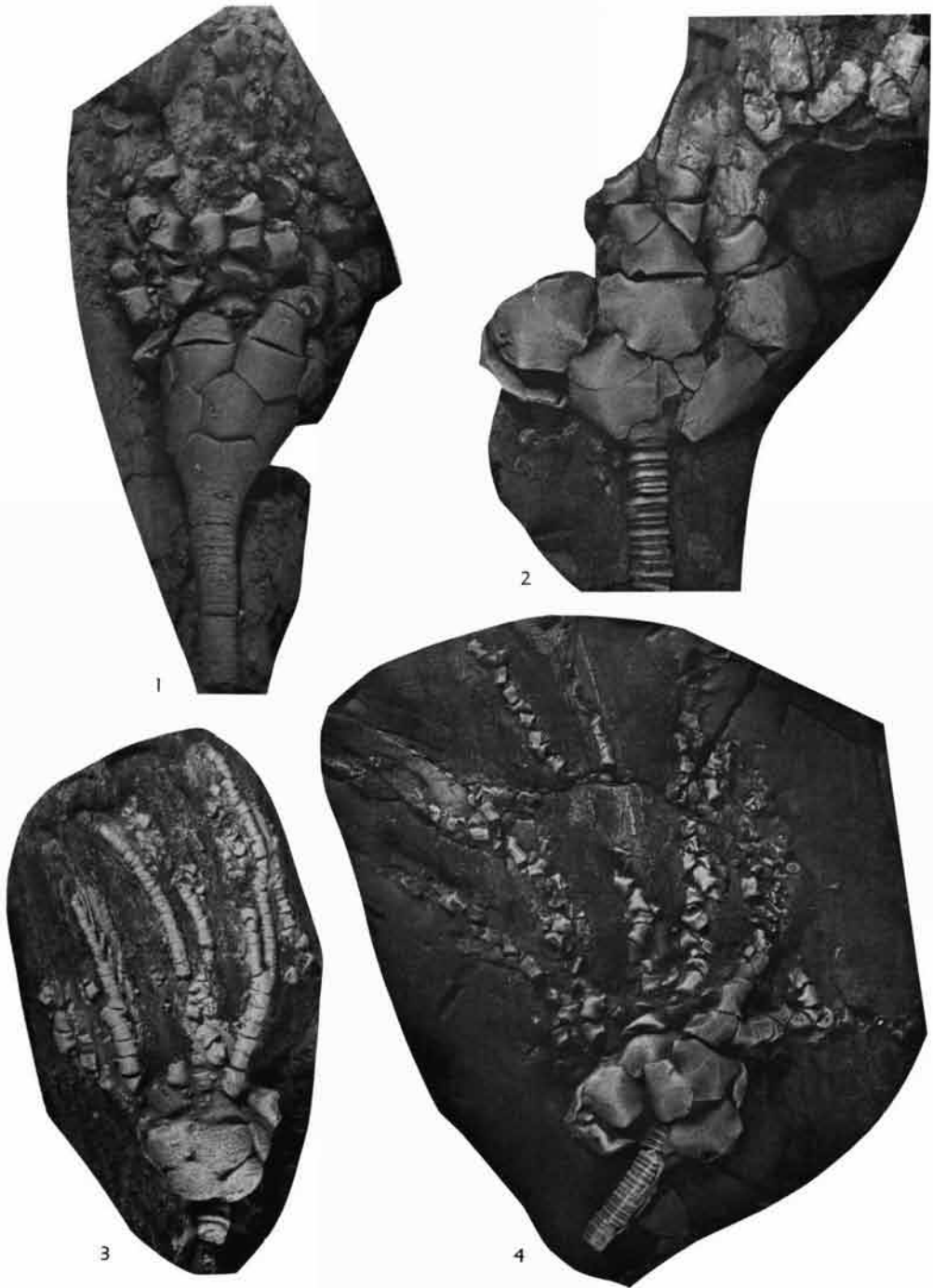


FIG. 10. *Elibatocrinus*, *Exoriocrinus*, and *Texacrinus* from Francis Shale, Upper Pennsylvanian, near Ada, Oklahoma.

1. *Elibatocrinus* cf. *E. leptocalyx* MOORE. Hypotype (OU 6165), partial crown viewed from side, $\times 1.6$.

2, 4. *Exoriocrinus rugosus* STRIMPLE & MOORE, n. sp.—
2. Paratype (OU6070), side view of partial crown,

$\times 1.6$.—4. Paratype (OU4791), side view of crown, $\times 1.6$.

3. *Texacrinus irradiatus* STRIMPLE. Hypotype (OU6162), side view of young crown, $\times 2.2$.

described species. Granular surface ornamentation with elongated primibrachs 1 are characters shared with the species. The present specimen (OU5680) has an almost complete set of arms. Proximal 4 or 5 secundibrachs are cuneiform; thereafter, secundibrachs are arranged biserially. The arms are relatively short, of uniform width, with only distal tips tapered.

Measurements of Hypotype (OU5680) in Millimeters

Height of crown	35.7
Width of cup (distorted)	20.8
Height of cup (estimated)	5.9
Width and length of radial	9.1, 5.4

FIGURED SPECIMEN.—OU5680, collected by ALLEN GRAFFHAM.

OCCURRENCE.—Francis Shale, Pennsylvanian (Missourian); brick pit at southeast edge of Ada, Pontotoc County, Oklahoma.

Family PELEOCRINIDAE Kirk, 1941

Genus EXORIOCRINUS Strimple & Moore, 1971

TYPE-SPECIES.—*Poteriocrinus lasallensis* WORTHEN, 1875, p. 526.

DIAGNOSIS.—Cup moderately large, medium bowl-shaped; infrabasals visible from side, three large anal plates in normal (primitive) arrangement; horizontally directed articular facets do not fill width of radials; primibrach 1 axillary, subsequent brachials cuneate, pinnule-bearing on alternating sides; proximal columnals pentagonal becoming round distalward.

OCCURRENCE.—Pennsylvanian (Desmoinesian-Missourian); USA (Oklahoma-Illinois).

EXORIOCRINUS RUGOSUS Strimple & Moore, n. sp.

Figures 8, 1, 4; 10, 2, 4

DESCRIPTION.—The existence of shallow depressions in areas about the corners of the plates is a feature shared with *Exorocrinus lasallensis* (WORTHEN, 1875). The presence of broad, radiating raised ridges passing between adjacent cup plates is a character shared with *E. pentacolumnus* (STRIMPLE, 1940, p. 6); however, the latter species has a surface marked by pronounced granulations and a relatively shorter cup. *E. ramonaensis* (STRIMPLE, 1939, p. 7) lacks depressions at the corners of the cup plates or pronounced ornamentation.

The arms branch on short, axillary primibrach 1 and bifurcate isotomously again. Secundibrachs are cuneate, rather narrow but thick, constricted in midsection. Ambulacral grooves are relatively shallow.

TYPES.—Holotype OU6070A, paratypes OU6070B, OU4791, OU5797, collected by ALLEN GRAFFHAM.

OCCURRENCE.—Francis Shale, Pennsylvanian (Missourian); brick pit at southeast edge of Ada, Pontotoc County, Oklahoma.

Family APOGRAPHIOCRINIDAE Moore & Laudon, 1943

Genus APOGRAPHIOCRINUS Moore & Plummer, 1940

TYPE-SPECIES.—*Apographiocrinus typicalis* MOORE & PLUMMER, 1941, p. 118.

DIAGNOSIS.—Crown relatively tall, slender and subcylindrical. Dorsal cup small, slightly truncate bowl-shaped with small, generally well-defined basal concavity. Cup plates slightly bulbous, basals transversely convex giving a scalloped appearance to summit of radials in ventral or dorsal view of cup; adsutural portions of radials extend into the articular area and form pronglike extensions; anal plate extends well above cup summit, faceted for two tube plates. Arms ten, uniserial (some brachials slightly cuneate), primibrach 1 axillary, alternate brachials pinnule-bearing on opposite sides. Column round.

OCCURRENCE.—Pennsylvanian (Desmoinesian) to Permian; USA, Indonesia.

APOGRAPHIOCRINUS sp. cf. *A. FACETUS* Moore & Plummer, 1940

Figure 5, 2

DISCUSSION.—A single well-preserved crown, with some 46 mm of stem preserved in the matrix, is closely related to *Apographiocrinus facetus*, from the Mineral Wells Formation, Canyon Group, Missourian, Brown County, Texas. In the holotype an area 1 mm or a little more in maximum length lies next to the radial articular facet, which is ornamented by coarse granules, but no sharp line of demarcation or angulation between this area and the smooth or faintly pitted lower surface of the radials. A sharp line of demarcation appears in the specimen from the Francis Shale. Future studies may refine distinctions of specific characters. Proximal columnals

are missing; those preserved have the appearance of a string of elongated beads.

HYPOTYPE.—OU5408, collected by ALLEN GRAFFHAM.

OCCURRENCE.—Francis Shale, Pennsylvanian (Missourian); brick pit at southeast edge of Ada, Pontotoc County, Oklahoma.

Family TEXACRINIDAE Strimple, 1961

DIAGNOSIS.—Crown elongate; arms, uniserial, slender or wide, brachials narrow and medium in length to wide and short, primibrach *I* axillary all rays, usually branching exotomously. Dorsal cup truncate cone-shaped with infrabasals upflared to subhorizontal; three anals in *CD* inter-ray. Anal tube unknown. Stem round.

GENERA.—*Texacrinus* MOORE & PLUMMER, 1940; *Ulrichierinus* SPRINGER, 1926.

OCCURRENCE.—Lower Mississippian (Osagian) to Upper Pennsylvanian (Missourian); USA.

Genus TEXACRINUS Moore & Plummer, 1940

TYPE-SPECIES.—*Texacrinus gracilis* MOORE & PLUMMER, 1940, p. 144.

DIAGNOSIS.—Crown elongate, somewhat expanded. Dorsal cup truncate cone- to bowl-shaped; infrabasals not shown in holotype of type-species and not visible in side view of other species, covered by stem; length of radials about two-thirds their width; three anal plates in advanced arrangement with radianal in dominant posterior position and two plates above (anal *X* and right tube plates) barely reach below or just above summit of radials. Arms slender to wide, uniserial, branch in each ray on primibrach *I* and thereafter with two or three divisions (or more), outward branching confined to the innermost parts of the ray (exotomous). Pinnules long, slender. Stem round.

SPECIES.—*Texacrinus gracilis* MOORE & PLUMMER, 1940, Brannon Bridge Member, Millsap Lake Formation, Desmoinesian, Parker County, Texas; *T. interruptus* STRIMPLE, 1952, *T. irradiatus* STRIMPLE, 1952, and *T. compactus* STRIMPLE, 1952, Francis Shale, Missourian, Pontotoc County, Oklahoma; *T. progressus* STRIMPLE, 1952, Barnsdall Formation, Missourian, Osage County, Oklahoma; *T. associatus* STRIMPLE, 1952, Oologah Limestone, Desmoinesian, Tulsa County, Oklahoma; *T. coniformis* STRIMPLE, 1961, Holdenville Formation, Desmoinesian, Okmulgee County, Oklahoma.

DISCUSSION.—The arms of a young specimen of *Texacrinus interruptus* STRIMPLE (1952, fig. 12-14) are narrow and delicate as in *T. gracilis*. The same condition is exhibited by a young specimen of *T. irradiatus* figured herein (OU 6162, Fig. 10, 3). For all other known crowns of the genus, including *T. coniformis*, the arms are wide and the brachials very short.

OCCURRENCE.—Pennsylvanian (Desmoinesian-Virgilian); USA (Texas-Oklahoma).

TEXACRINUS IRRADIATUS Strimple, 1952, p. 218

Figures 5, 3; 6, 2; 10, 3

DISCUSSION.—Several excellently preserved topotype specimens are available in the present collection. The species is the most abundant form in the colony.

Dorsal cup medium-sized, with basally impressed bowl. Infrabasals confined to small basal concavity, entirely obscured by proximal columnals. Three anal plates in remarkably constant arrangement. Advanced placement of the radianal in dominant posterior position with large anal *X* plate to the left above and small right tube plate to the right above. The distal facets of anal *X* and right tube plates form a confluent plane.

Number of arms is now known to be 40, 10 more than previously reported. Branching is exotomous (bifurcating from the 2 main trunks outwardly).

TYPES.—Topotypes (metatypes) OU6162, OU6068, OU5409B, OU6167, collected by ALLEN GRAFFHAM.

OCCURRENCE.—Francis Shale, Pennsylvanian (Missourian); brick pit at southeast edge of Ada, Pontotoc County, Oklahoma.

TEXACRINUS COMPACTUS Strimple, 1952

DISCUSSION.—This species, not represented in the present collection, is distinguished from other described species from the Francis Shale by the compact nature of the cup and small stem. It may be a variant of *Texacrinus irradiatus*.

OCCURRENCE.—Francis Shale, Pennsylvanian (Missourian); brick pit at southeast edge of Ada, Pontotoc County, Oklahoma.

TEXACRINUS INTERRUPTUS Strimple, 1952

DISCUSSION.—This species is not represented in the collection under study. It is distinguished from other described forms in having more pronounced tumidity of cup plates, decided pitlike

depressions at angles of the cup plates and sharp definition between alternately expanded columnals. *Texacrinus interruptus* may be a specialized variant of *T. irradiatus*.

Occurrence.—Francis Shale, Pennsylvanian (Missourian); brick pit at southeast edge of Ada, Pontotoc County, Oklahoma.

Family ETHELOCRINIDAE Strimple, 1961

Genus PARETHELOCRINUS Strimple, 1961

TYPE-SPECIES.—*Parethelocrinus ellipticus* STRIMPLE, 1961, p. 83.

DIAGNOSIS.—Crown elongate, subcylindrical. Dorsal cup broad, medium in height, with little or no basal concavity; infrabasal disc small, subhorizontal; two large anal plates. Arms vary from 12 to 16, biserial, pinnulate, primibrach 1 axillary in all rays and left anterior (*E* ray) and right anterior (*B* ray) remain unbranched above. Second bifurcation, when present, is on secundibrach 1. Stem small, round.

DISCUSSION.—*Parulocrinus* has similar arm and cup structure to that of *Parethelocrinus* but is more primitive in having proportionately larger infrabasals which are slightly upflared and in many having a small right tube plate notching the summit of the cup.

Occurrence.—Pennsylvanian (Desmoinesian-Missourian); USA.

PARETHELOCRINUS sp.

Figure 6, 6

DISCUSSION.—A single poorly preserved crown is in the collection. The cup has collapsed and exact comparison with other forms is not attempted here.

FIGURED SPECIMEN.—OU4784, collected by ALLEN GRAFFHAM.

Occurrence.—Francis Shale, Pennsylvanian (Missourian); brick pit at southeast edge of Ada, Pontotoc County, Oklahoma.

Family PIRASOCRINIDAE Moore & Plummer, 1940

Genus LAUDONOCRINUS Moore & Plummer, 1940

TYPE-SPECIES.—*Hydreionocrinus subsinuatus* MILLER & GURLEY, 1894, p. 40.

DIAGNOSIS.—*Laudonocrinus* is distinguished from other pirasocrinids in having a moderately low, smooth, bowl-shaped cup, lacking impressed sutures, flattened or slightly concave base. Posterior (*CD*) interradius broad, three anal plates in normal (primitive) arrangement. Arms 20, uniserial, primibrach 1 elongate, with small distal spine. Anal tube stout, terminating with flat umbrellalike platform of small plates surrounded by seven large, spadelike plates extended as long spines.

Occurrence.—Pennsylvanian (Desmoinesian-Missourian); USA (Missouri-Illinois-Oklahoma-Texas).

LAUDONOCRINUS sp. cf. *L. SUBSINUATUS* (Miller & Gurley), 1894

Figure 6, 5

DISCUSSION.—A single dorsal cup with 2 associated elongated primibrachs is closely related to *Laudonocrinus subsinuatus*. The infrabasals are more prominent than typical of the species. The present specimen is more comparable to hypotypes from the LaSalle Limestone described by STRIMPLE & MOORE (1971).

FIGURED SPECIMEN.—OU6068B, collected by ALLEN GRAFFHAM.

Occurrence.—Francis Shale, Pennsylvanian (Missourian); brick pit at southeast edge of Ada, Pontotoc County, Oklahoma.

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