THE UNIVERSITY OF KANSAS

PALEONTOLOGICAL CONTRIBUTIONS

November 15, 1974 Paper 73

FOSSIL CRINOID STUDIES[1]

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[1] Manuscript received February 21, 1974.

PART 1

MISCELLANEOUS PENNSYLVANIAN CRINOIDS FROM KANSAS, OKLAHOMA, AND NEBRASKA

ABSTRACT

The crinoids described herein provide additional stratigraphic and geographic data concerning the distribution of 28 different species, two of which, *Aglaocrinus supplantus* Pabian & Strimple and *Plaxocrinus macrospiniferus* Pabian & Strimple, are new. The existence of topotypes of 4 species, *Graffhamicrinus acutus* Strimple, *G. magnificus* (Strimple), *G. aristatus* (Strimple) and *Metaperimestocrinus spiniferus* Strimple is recorded.

INTRODUCTION

The crinoids described herein are from several diverse sources, and were collected by a number of collectors over about a 70-year span. While preparing the publication "Record in Rock" (Pabian, 1970), a thorough search of the invertebrate fossil collections of the University of Nebraska State Museum was made in order to catalogue the fossil genera known to have been found within the state. As a result of this search, a number of crinoids from Kansas, Oklahoma, and Missouri were discovered. Most of the Paleozoic invertebrate fossil collections in the University of Nebraska State Museum were made by staff members of the University of Nebraska Conservation and Survey Division. In 1969, the curating of the collections of the Nebraska Conservation and Survey Division became the responsibility of the State Museum. These crinoids were collected by Erwin Hinkley Barbour and Mrs. Barbour (*ca.* 1900), E. G. Woodruff (*ca.* 1905), George Evert Condra and Charles E. Busby (*ca.* 1930), E. C. Reed (*ca.* 1940), and Allen Graffham (*ca.* 1946). In addition to the above collectors, material gathered by one of the authors (Pabian) from Oklahoma and Kansas between 1964 and 1968 is included. The bulk of the material studied, however, is from Kansas.

SYSTEMATIC PALEONTOLOGY

Phylum ECHINODERMATA Laske, 1778

Subphylum PELMATOZOA Leuckart, 1848

Class CRINOIDEA Miller, 1821

Subclass FLEXIBILIA Zittel, 1895

Order SAGENOCRINIDA Springer, 1913

Family EURYOCRINIDAE Moore & Strimple, 1973

Genus PARAMPHICRINUS Strimple & Moore, 1971

PARAMPHICRINUS sp. cf. P. POUNDI (Strimple, 1939)

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

Amphicrinus poundi Strimple, 1939, p. 5, pl. 2, fig. 18, 19; Strimple & Moore, 1971, p. 47, pl. 23, fig. 1a,b.

Remarks.—As the exterior of the dorsal cup and several rays cannot be observed, no attempt is made here to assign the specimen studied to a described species. The interior most closely resembles the species described as *Amphicrinus poundi* Strimple, here referred to *Paramphicrinus poundi* (Strimple), new combination. Under 10-power magnification the sutures between plates show a zigzag pattern (Fig. 1, *1*; *2, 1*).

Material Studied.—Hypotype UNSM 10449, from Cement City Limestone, Drum Formation, Kansas City Group, Missourian Stage (Upper Pennsylvanian), sec. 28, T. 27 N., R. 13 E., Washington County, Oklahoma.

Subclass INADUNATA Wachsmuth & Springer, 1885

Order CLADIDA Moore & Laudon, 1943

Suborder POTERIOCRININA Jaekel, 1918

Superfamily PIRASOCRINACEA Moore & Laudon, 1943

Family PIRASOCRINIDAE Moore & Laudon, 1943

Genus PLAXOCRINUS Moore & Plummer, 1938

Type Species.—*Hydreionocrinus crassidiscus* Miller & Gurley, 1894, p. 43.

Diagnosis.—See Moore & Plummer, 1940, p. 187, emended by Strimple, 1961, p. 45.

Remarks.—The low cup, with distal ends of tumid basals readily visible in side view and broad shallow basal concavity are distinctive of *Plaxocrinus*. Strimple, 1961, restricted the genus to characters of the type species, which is a dorsal cup lacking arms. Characters of the arms and of the platform-like termination of the anal sac were based by Strimple (1961, p. 46) on species for which such information was available. The primibrachs *1* are axillary, low, and projected as heavy spines. Other axillary brachials were noted to be nonspinose. A small anal sac platform had from 7 to 9 outwardly directed spinose plates about the perimeter. Intimate relationship between *Stenopecrinus* and *Plaxocrinus* was suggested.

A specimen under consideration here has all of the characteristics of *Plaxocrinus* except that upper axillary brachials are spinose, which is

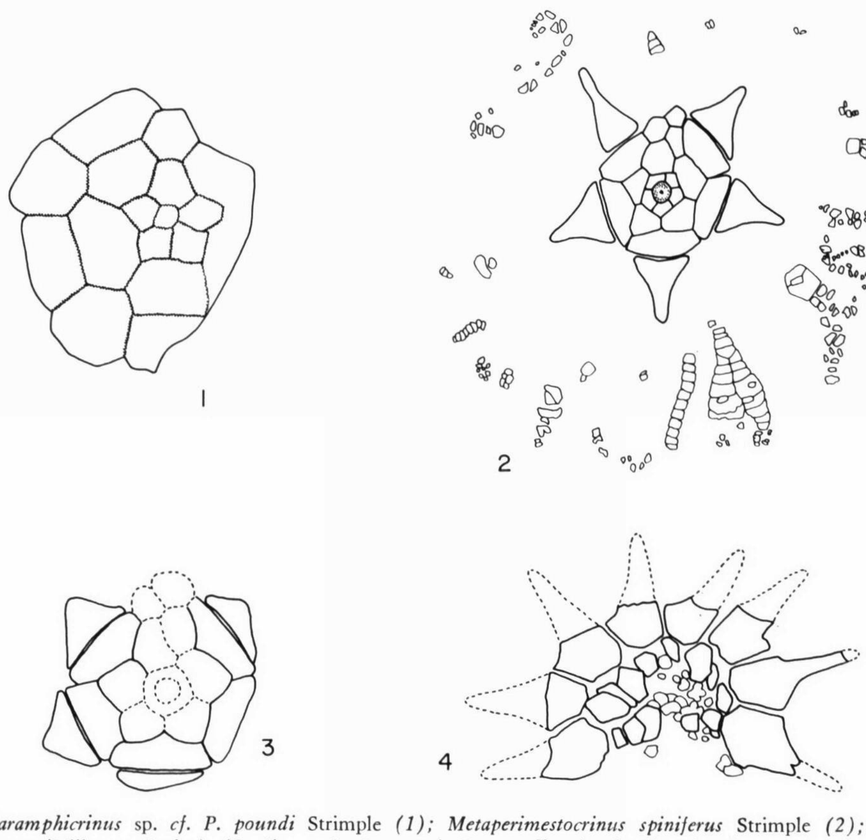

FIG. 1. *Paramphicrinus* sp. *cf. P. poundi* Strimple *(1)*; *Metaperimestocrinus spiniferus* Strimple *(2)*; *Sciadiocrinus acanthophorus* (Miller & Gurley) *(3, 4)*.——*1. P.* sp. *cf. P. poundi* Strimple, line drawing of dorsal cup, hypotype, UNSM 10449, showing zigzag nature of plate sutures, ×2.——*2. M. spiniferus* Strimple from the Holdenville Formation, Desmoinesian (Middle Pennsylvanian), near Beggs, Oklahoma. Line drawing of hypotype crown, UNSM 10466, showing worm borings on arms of *A* and *B* rays, ×1.——*3,4. S. acanthophorus* Miller & Gurley, from the Haskell Limestone, Shawnee Group, Virgilian (Upper Pennsylvanian), near Louisville, Nebraska; hypotype, UNSM 10411, dorsal view of crushed crown and ventral view of umbrella-like anal sac termination, ×2.

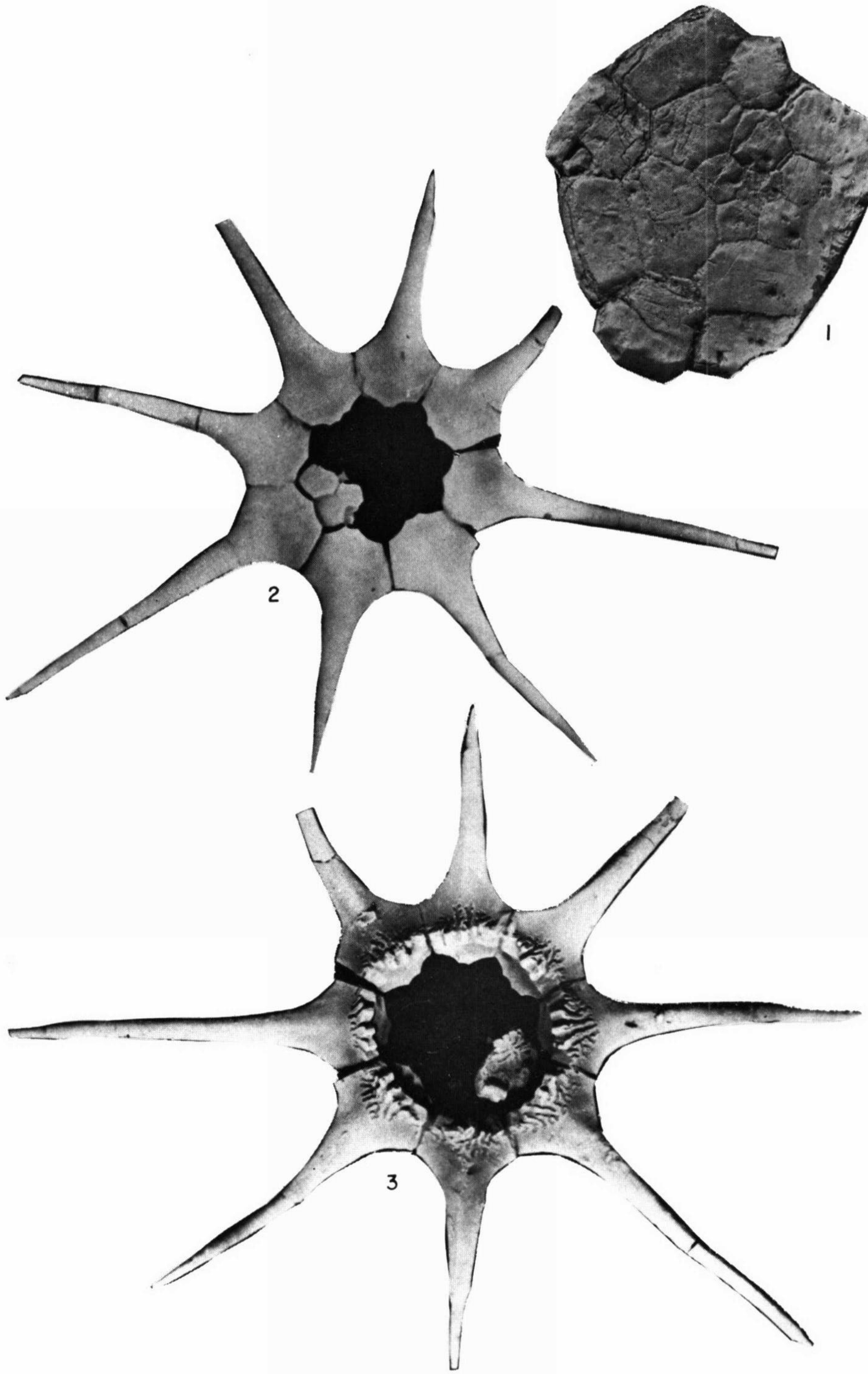

FIG. 2. *Paramphicrinus* sp. *cf. P. poundi* Strimple *(1)*; *Plaxocrinus macrospiniferus* Pabian & Strimple, n. sp. *(2,3)*.——*1. Paramphicrinus* sp. *cf. P. poundi* Strimple; hypotype, UNSM 10499, ventral view, ×3.——*2,3. Plaxocrinus macrospiniferus* Pabian & Strimple, n. sp.; holotype, UNSM 10412, ventral and dorsal views of umbrella termination of anal sac, ×1.

atypical. It is described as *P. macrospiniferus* Pabian & Strimple, new species. Relationship with *Anchicrinus* Strimple & Watkins, 1969, is also considered as a distinct possibility.

Occurrence.—Lower Pennsylvanian (Morrowan)-Upper Pennsylvanian (Virgilian), Lower Permian, North America.

PLAXOCRINUS CRASSIDISCUS (Miller & Gurley, 1894)

Hydreionocrinus crassidiscus Miller & Gurley, 1894; p. 43, pl. 6, fig. 18, 19.

Plaxocrinus crassidiscus Moore & Plummer, 1938, p. 279; Shimer & Shrock, 1944, p. 163, pl. 62, fig. 7; pl. 63, fig. 7.

Remarks.—The specimens studied add little to our knowledge of *Plaxocrinus crassidiscus* except concerning its stratigraphic and geographic distribution. The holotype was likely collected from the Wyandotte Limestone at Kansas City, Missouri, which is in the middle of the Missouri Series (Moore & Plummer, 1938, p. 278). The Nebraska specimens indicate this species extends at least into the lower Virgil Series.

Material Studied.—Hypotypes UNSM 10458 and UNSM 10459 from Haskell Limestone Member, Cass Formation, Douglas Group, Virgilian Stage (Upper Pennsylvanian), NE ¼, NE ¼, sec. 30, T. 12 N., R. 12 E., Cass County, Nebraska. Hypotype UNSM 10498, Stoner Limestone Member, Stanton Formation, Lansing Group, Missourian Stage (Upper Pennsylvanian), Old Burlington Quarry, sec. 9, T. 12 N., R. 10 E., Cass County, Nebraska.

PLAXOCRINUS MACROSPINIFERUS
Pabian & Strimple, new species
Figures 2, *2, 3*; 3, *1-7*

Description.—The dorsal cup is medium, truncate bowl-shaped and has the primibrachials attached to the radials. The five infrabasals are kite-shaped and form a pentagonal, nearly planate circlet. The columnar cicatrix is about two-thirds the diameter of the infrabasal circlet and bears a weak, crenulated stem attachment. The proximal portions of the five basals slope downward slightly and are not seen in the side view of the cup. The *AB, DE,* and *EA* basals are pentagonal.

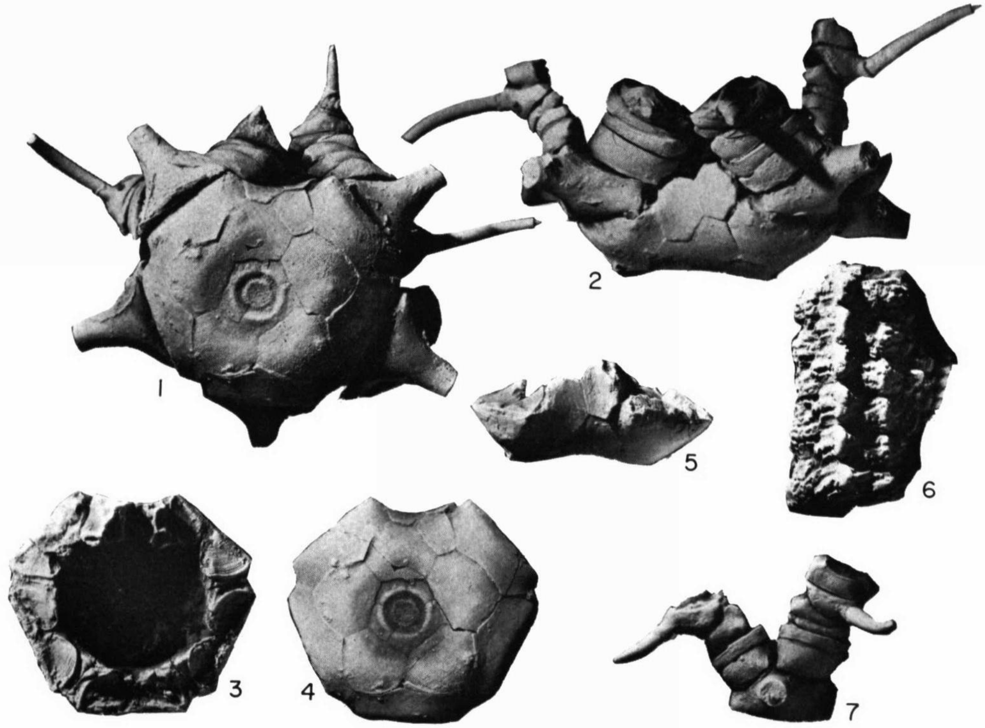

FIG. 3. *Plaxocrinus macrospiniferus* Pabian & Strimple, n. sp., from the Eudora Shale, Missourian (Upper Pennsylvanian), Montgomery County, Kansas.——*1,2*. Dorsal and posterior views of reassembled, partial crown of holotype, UNSM 10412.——*3,4,5*. Ventral, dorsal, and posterior views of cup before arms were replaced.——*6*. Part of anal tube.——7. Lower arm of *D* ray, all ×1.

BC and *CD* basals are hexagonal to accommodate the primanal (radianal) plate. The medial portions of the *AB, BC, DE,* and *EA* basals form the basal plane of the cup. The distal ends of the basals curve upward and extend about one-third the height of the cup. The radials are epaulette-shaped with the exception of the *C* radial, which is irregularly pentagonal in order to accommodate the primanal and tertanal (right tube) plates. Proximal tips of the radials extend to the basal plane of the cup. The proximal parts of the radials lie in a flat plane and curve sharply about midway; their distal ends rise nearly vertically, giving the cup a truncated-funnel cross section. There is a deep notch between the distal junctions of the radials and the cup has a hexagonal outline when viewed from above or below.

The primanal is an irregular pentagon about twice as wide as long; it is bounded by the *CD* and *BC* basals below and the *C* radial, secundanal (anal *X*) and tertanal plates above. Secundanal is long, hexagonal, and bounded by the *CD* basal below, the *D* radial, primanal and tertanal laterally. The tertanal plate is hexagonal. Both the secundanal and tertanal plates are faceted for the reception of an anal sac above.

The peneplenary, radial articulatory facets slope outward gently and are about twice as wide as long. The outer marginal ridge is well defined but in low relief. There is a wide, shallow outer marginal furrow. The ligament pit is deep and the transverse ridge is sharp and denticulate. Lateral slopes rise up to a sharp lateral ridge. The muscle areas gradually sink into a deep central pit that is connected to a large intramuscular notch by a short furrow.

The five axillary primibrachials protrude to form large, blunt spines, the ends of which are recessed. These are followed by a parallelogram-shaped secundibrachial that is about twice as wide as long.

The tegmen is covered by a flat roof made of numerous, small, polygonal platelets, which are girdled with eight, long protruding spines. The anal sac is composed of numerous, coarsely ornamented plates.

Measurements.—See Appendix 1.

Remarks.—The specimen was collected in the fall of 1968 by one of the authors (Pabian) while on a department field trip with the University of Nebraska. A careless step by one of the party members crushed the upper portion of the crown and the arms were never put back together.

Plaxocrinus macrospiniferus appears to be closely related to *P. aplatus* Moore & Plummer (1940), particularly to the paratype illustrated by Moore & Plummer (*ibid.,* pl. 9, fig. 2). *P. aplatus* is typically from Desmoinesian rocks of Texas. There is also the possibility of relationship with *Anchicrinus* Strimple & Watkins (1969) which is also typically from Desmoinesian rocks of Texas. Transition from *Anchicrinus toddi* Strimple & Watkins (1969) would be through change in lateral cup walls from erect to subhorizontal position, development of a decided basal concavity and extension of the axillary first primibrachs as thick spines.

P. macrospiniferus is atypical of *Plaxocrinus* as defined by Strimple (1961, p. 45-48) in that axillary brachials above the first bifurcation are spinose. A revision of the Pirasocrinidae and related forms is being attempted by Ron Lewis, a Master's Degree candidate at the University of Iowa, and is therefore not considered here.

Material Studied.—Holotype UNSM 10412, collected from the Eudora Shale, Stanton Formation, Missourian Stage (Upper Pennsylvanian) exposed in the roadcut in the NE ¼, sec. 35, T. 32 S., R. 14 E., about 6 miles west of Independence, Montgomery County, Kansas.

Genus SCIADIOCRINUS
Moore & Plummer, 1938

Type Species.—*Zeacrinus (Hydreionocrinus) acanthophorus* Meek & Worthen, 1870, p. 28.

Other Included Species.—*Sciadiocrinus disculus* Moore & Plummer, 1940; *S. harrisae* Moore & Plummer, 1940; *S. ? crassacanthus* Moore & Plummer, 1938; *S. tegillum* Strimple & Moore, 1971; *Eupachycrinus platybasis* White, 1883; *Schistocrinus confertus* Moore & Plummer, 1940; *Schistocrinus planulatus* Moore & Plummer, 1940; *Plaxocrinus obesus* Moore & Plummer, 1940; *S. llanoensis* Strimple & Watkins, 1969; *Pirasocrinus invaginatus* Strimple, 1951; *Athlocrinus clarus* Strimple, 1962; *Athlocrinus clypeiformis* Moore & Plummer, 1940; *S. humilis* Strimple, 1951; *S. breweri* Webster & Lane, 1970; *Hydreionocrinus pentagonus* Miller & Gurley, 1890; *S. cascus* Moore & Strimple, 1973.

Diagnosis.—See Moore & Plummer, 1940, p. 228, or Strimple & Moore, 1971, p. 20.

Remarks.—As pointed out by Moore & Plummer (1940, p. 229) the cup of *Sciadiocrinus* is much like that of *Pirasocrinus* Moore & Plummer, 1940, but the arms are quite different. It might also be added the terminating platform of the anal sacs are also quite different. A superficial resemblance to the cup of the unrelated Mississippian genus *Adinocrinus* Kirk was also noted by those authors.

Occurrence.—Lower Pennsylvanian (Morrowan)-Upper Pennsylvanian (Virgilian), USA (Nebraska, Utah, Arizona, Oklahoma, Kansas, Texas, Missouri, Arkansas, Illinois).

SCIADIOCRINUS ACANTHOPHORUS
(Meek & Worthen, 1870)
Figures 1, *3, 4*

Zeacrinus (Hydreionocrinus?) acanthophorus Meek & Worthen, 1870, p. 28; 1872, p. 563, pl. 24, fig. 11.
Zeacrinus acanthophorus Barbour, 1903, p. 127; Woodruff, 1906, p. 264, pl. 7, fig. 2.
Hydreionocrinus acanthophorus Wachsmuth & Springer, 1879; Keyes, 1894, p. 215, pl. 26, fig. 6.
Sciadiocrinus acanthophorus Moore & Plummer, 1938, p. 275, text-fig. 38; 1940, p. 229, text-fig. 50.

Remarks.—The specimen under study, a distorted crown with broken sac-spines intact, is probably the same as that reported by E. H. Barbour (1903, p. 127). Woodruff (1906, p. 264) reported *Zeacrinus acanthophorus (=Sciadiocrinus acanthophorus)* on the basis of sac-spines alone. The number on the specimen indicates it was collected July 16, 1899, probably by Eleanor (Mrs. E. H.) Barbour. No stratigraphic or geographic details were given by Barbour (1903, p. 127) regarding this specimen. Woodruff (1906, p. 264) reported his specimens as being from Cedar Creek, Weeping Water, and Rock Bluff. These areas include the stratigraphic section ranging from the Argentine Limestone, Upper Kansas City Group, Upper Missourian through the Ervine Creek Limestone, Upper Shawnee Group, in part of the Lower Virgilian. R. R. Burchett (personal commun.) indicated to the authors that the limestone matrix enclosing the specimen most closely resembled the Cass (Haskell) Limestone (Lower Virgilian). Exposures south of Cedar Creek, in the C, S ½, NE ¼, NE ¼, NE ¼, sec. 30, T. 12 N., R. 12 E., Cass County, include the Cass and Lawrence Formations. If the above specimen is the one referred to by Barbour (1903), then it probably was collected from the above horizon and locality.

Material Studied.—Hypotype UNSM 10411.

SCIADIOCRINUS PENTAGONUS
(Miller & Gurley, 1890)
Figure 4, *1*

Hydreionocrinus pentagonus Miller & Gurley, 1890, p. 17, pl. 2, fig. 6, 7; 1894, p. 339, pl. 2, fig. 6, 7; Keyes, 1894, p. 215.
?Sciadiocrinus pentagonus Moore & Plummer, 1938, p. 276; Knapp, 1969, p. 378, 388.
Adinocrinus pentagonus Moore & Plummer, 1940, p. 71, 240.

Remarks.—The specimen studied most closely resembles the figured holotype, *Hydreionocrinus pentagonus* Miller & Gurley. Relationship with *Sciadiocrinus* is demonstrated by the basals, which are entirely within the basal concavity of the cup and are not visible in side view.

The anal series of the cup at hand is narrow and distinctive, the primanal (radianal) being long and narrow and contacting the *BC* basal below and the *C* radial laterally. Secundanal (anal *X*) is an irregularly pentagonal (spear-shaped) plate, its proximal tip just touching the *CD* basal below and its sides touching the *D* radial and primanal. A very large tertanal (right tube) plate touches primanal and secundanal below and is bounded left-laterally by a tube plate.

Miller and Gurley's type specimen was collected from rocks of Missourian age near Kansas City, Missouri. Moore & Plummer (1940, p. 71) indicated the holotype was collected in Jackson County. The specimen under study was collected from the Spring Hill Limestone Member, Plattsburg Formation, Lansing Group, Missourian Stage (Upper Pennsylvanian); rocks of closely related age to those containing Miller and Gurley's specimen.

Material Studied.—Hypotype UNSM 10416, was collected from the abandoned quarry near Wilson County State Park on the west side of U.S. Highway 75, in the SE ¼, SE ¼, sec. 17, T. 27 S., R. 16 E., Wilson County, Kansas.

Genus METAPERIMESTOCRINUS Strimple, 1961

Type Species.—*Metaperimestocrinus spiniferus* Strimple, 1961, p. 36-39, text-fig. 13a,b; pl. 4, fig. 3-7, pl. 18, fig. 5.

Other species included.—*Metaperimestocrinus trapezoidalis* Strimple, 1962, p. 35-37, pl. 7, fig. 15-18; *Metaperimestocrinus verrucosus* Webster

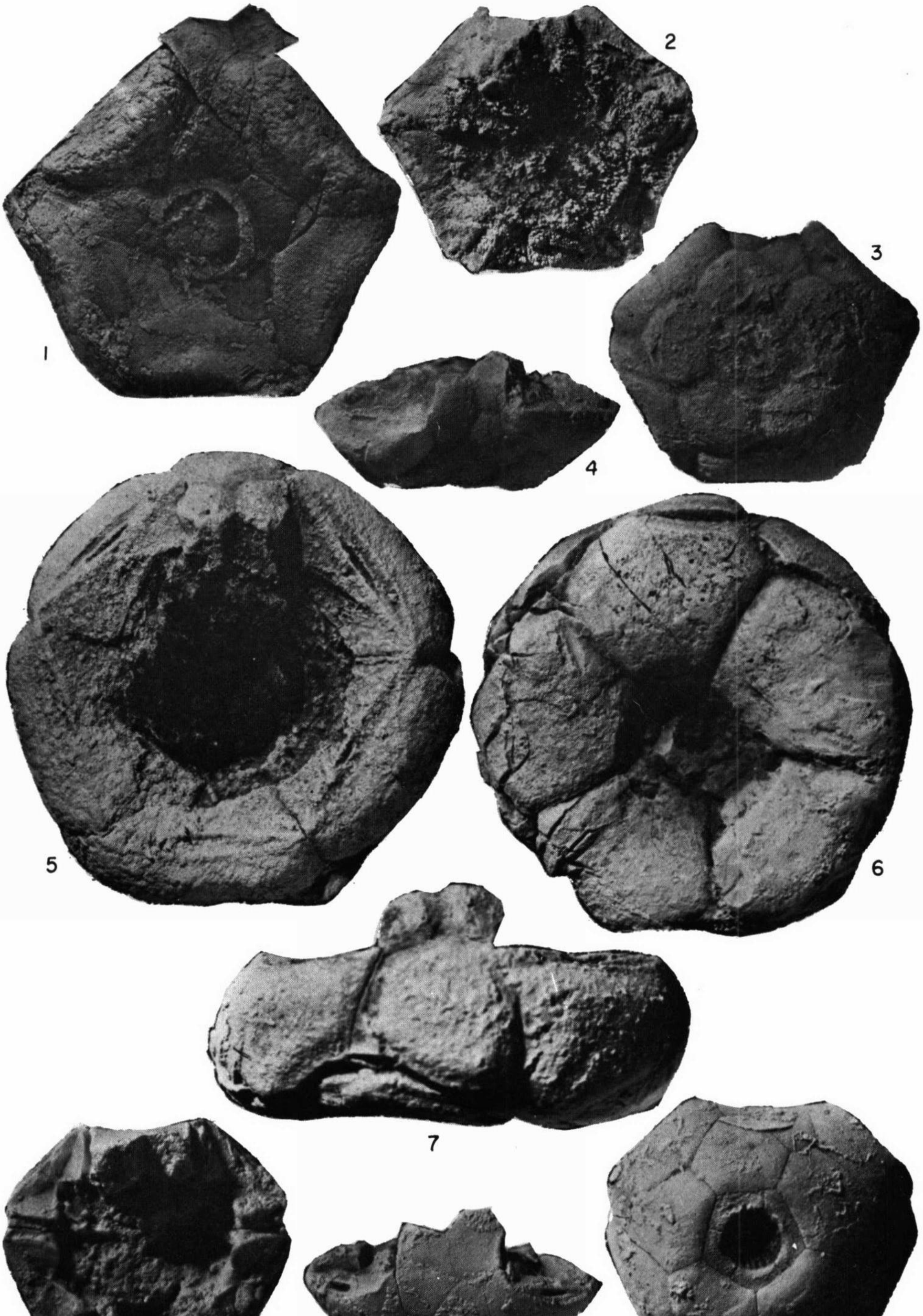

FIG. 4. *(For explanation see facing page.)*

& Lane, 1970, p. 283, 284, pl. 55, fig. 18, 19, pl. 57, fig. 10-15.

Diagnosis.—See Strimple, 1961, p. 36-39.

Occurrence.—Lower Pennsylvanian (Morrowan), USA.

METAPERIMESTOCRINUS SPINIFERUS Strimple, 1961
Figure 1, 2

Metaperimestocrinus spiniferus Strimple, 1961, p. 37-39, text-fig. 13a,b; pl. 7, fig. 3-7; pl. 18, fig. 5.

Remarks.—Strimple (1961, p. 15-16) indicated that very little parasitic life was associated with the Holdenville crinoids and stated that the arms of only *Schedexocrinus gibberellus* and *Plaxocrinus normalis* had cyst-like swellings. Such swellings are to be seen on the *A* and *B* rays of *Metaperimestocrinus spiniferus,* the swelling being located in the tertibrachials in the former case and near the last secundibrachial in the latter (Fig. 1,*2*).

Material Studied.—Hypotype UNSM 10466, Holdenville Formation, Desmoinesian Stage (Middle Pennsylvanian), NE ¼, sec. 24, T. 15 N., R. 11 E., Okmulgee County, Oklahoma.

METAPERIMESTOCRINUS sp. cf. M. SPINIFERUS Strimple, 1961
Figure 4, *2-4*

Remarks.—The cup of the specimen studied differs from the cup of the holotype of *Metaperimestocrinus spiniferus* in lacking distinct depressions at the angles of cup plates and in having a cup with a strongly pentagonal outline rather than a circular one. Once the variation in *M. spiniferus* can be established, the specimen described may prove to be conspecific. It differs from *M. spiniferus* by having a roughened surface (*M. trapezoidalis* has fine, pointed granules) and impressed sutures between cup plates.

Material Studied.—Hypotype UNSM 10461, from Spring Hill Limestone, Plattsburg Formation, Lansing Group, Missourian Stage (Upper Pennsylvanian), SE ¼, SE ¼, sec. 17, T. 27 S., R. 16 E., Montgomery County, Kansas.

Genus STENOPECRINUS Strimple, 1961

Type Species.—*Perimestocrinus planus* Strimple, 1952, p. 787-788. pl. 112, fig. 4-9.

Other Species Included.—*Perimestocrinus papillatus* Strimple, 1962; *P. impressus* Moore & Plummer, 1940; *P. mosleyi* Strimple, 1951; *Stenopecrinus rugosus* Strimple, 1961; *S.? herophilus* Lane & Webster, 1966; *S. longus* Strimple & Watkins, 1969; *Perimestocrinus hexagonus* Strimple, 1952.

Diagnosis.—See Strimple, 1961, p. 39-40.

STENOPECRINUS PLANUS (Strimple, 1961)

Perimestocrinus planus Strimple, 1952, p. 787-788, pl. 112, fig. 4-9.

Stenopecrinus planus Strimple, 1961, p. 40-42, text fig. 5a, b; pl. 1, fig. 4, 5; Strimple & Moore, 1971, p. 21, pl. 12, fig. 1a, b; fig. 2a.

Remarks.—The specimens studied add little to our knowledge of *Stenopecrinus planus* except for geographic and stratigraphic details. This species appears to have a rather short range-zone, the earliest individuals occurring in the Hogshooter of Oklahoma. Current collections show it is abundant in the Wann of Oklahoma, Stanton of Nebraska and La Salle of Illinois. It has not previously been reported from Kansas.

Material Studied.—Hypotype UNSM 10462, Spring Hill Limestone, Plattsburg Formation, Lansing Group, Missourian Stage (Upper Pennsylvanian), SE ¼, SE ¼, sec. 17, T. 27 S., R. 16 E., Wilson County, Kansas. Hypotype UNSM 10468, Lost City [=Hogshooter (=Winterset)] Limestone, Dennis Formation, Kansas City Group, Missourian Stage (Upper Pennsylvanian), Gould's "Lost City" type locality, Lost City, 2 miles southwest of Tulsa, Oklahoma. Hypotypes UNSM 10476-UNSM 10477, Lost City Limestone, Sand Springs, Oklahoma.

Superfamily CROMYOCRINACEA Bather, 1890

Family CROMYOCRINIDAE Bather, 1890

Genus AGLAOCRINUS Strimple, 1961

[=*Tarachiocrinus* Strimple, 1961 (*pro Ataxiacrinus* Strimple, 1961, *non* Lyon, 1869)]

FIG. 4. *Sciadocrinus pentagonus* Miller & Gurley *(1); Metaperimestocrinus* sp. *cf. M. spiniferus* Strimple *(2-4); Aglaocrinus supplantus* Pabian & Strimple, n. sp. *(5-7); Laudonocrinus subsinuatus* Miller & Gurley *(8-10)*.——*1. S. pentagonus* Miller & Gurley; hypotype, UNSM 10416, dorsal view, ×2.——*2-4. M.* sp. *cf. M. spiniferus* Strimple; hypotype, UNSM 10461, ventral, dorsal, and posterior views, ×2.——*5-7. A. supplantus* Pabian & Strimple, n. sp.; holotype, UNSM 10417, ventral, dorsal, and posterior views, ×2.——*8-10. L. subsinuatus* Miller & Gurley; hypotype, UNSM 10423, ventral, posterior, and dorsal views, ×3.

Type Species.—Ethelocrinus magnus Strimple, 1939.

Other Species Included.—Ethelocrinus iatani Strimple, 1949; *E. expansus* Strimple, 1938; *Parulocrinus compactus* Moore & Plummer, 1940; *Parulocrinus pustulosus* Moore & Plummer, 1940; *Ataxiacrinus multiramus* Strimple, 1961; *Mooreocrinus meadowensis* Strimple, 1949; *A. supplantus* Pabian & Strimple, new species.

Diagnosis.—See Strimple, 1961, p. 86. Emended to include species with three anal plates.

Remarks.—Aglaocrinus is recognized from the Atokan of Texas, the Desmoinesian and the Missourian of Nebraska, Oklahoma, Texas and Kansas. It differs from other cromyocrinids in having the cup sutures deeply impressed in V-shaped depressions, a relatively broad basal invagination, irregular or undulating plate surfaces (exception, *A. compactus*), and more than ten biserial arms.

AGLAOCRINUS SUPPLANTUS Pabian & Strimple, new species

Figure 4, 5-7

Description.—The dorsal cup is a medium bowl with a deep, funnel-shaped basal concavity, a broad base and a constricted summit. There are five infrabasals, the proximal tips covered by the stem and the extreme distal portions of which slope downward at about 45 degrees. The infrabasals flex sharply and slope at about 75 degrees and extend for about half the height of the basal concavity. There is a round, flat-lying columnar cicatrix with a pentalobate lumen at the center of the infrabasal circlet. The *AB, BC, DE* ,and *EA* basals are large, pentagonal plates. Their proximal portions slope downward at about 75 degrees, this slope diminishing distally such that the basal plane of the cup is distally located. The basals then recurve sharply, their distal tips rising to about 0.3 the height of the cup, where their attitude is nearly vertical. The *CD* basal is an irregular hexagon, so shaped in order to accommodate the extremely large, five-sided radianal which is the dominant plate of the anal series and rises above the radial summit of the cup. The five radials are large epaulette-shaped plates, the proximal tips of which extend to the basal plane of the cup. The distal parts of the radials continue in the curvature of the proximal parts of the basals; they then curve sharply, their medial portions being nearly vertical and then curve inward abruptly near the summit. The *C* and *D* radials are separated by the primanal (radianal), which is followed by small, four-sided secundanal (anal *X*) and tertanal (right tube) plates, both of which lie above the radial summit of the cup.

The radial articulating facets are large and slope inward. The outer marginal ridge is sharp and well defined. There is a deep outer ligament furrow and a sharp ligament pit ridge. The ligament pit is very deep and a ligament pit furrow is well defined. The transverse ridge is sharply defined, has a number of coarse but poorly defined denticles and extends almost the entire width of the radial facet. The lateral slopes and ridges are present but not sharply delineated. The muscle areas slope into a broad, central pit which extends nearly to the transverse ridge.

Measurements.—See Appendix 1.

Remarks.—Aglaocrinus supplantus is apparently closely related to *A. compactus* but is considerably more advanced in the positioning of anal plates and in having a broader deeper basal concavity. *A. supplantus* also has an uneven or wave-like surface which is typical of the genus but is atypical of *A. compactus.*

Aglaocrinus compactus has been reported from the Hogshooter Formation of Oklahoma by Strimple & Cocke (1973, p. 151) and is known by one of us (Strimple) to occur commonly in the Winterset Limestone Member of the Dennis Formation west of Coffeyville, Montgomery County, Kansas. The presence of the Hogshooter Limestone in Kansas has not been confirmed by intensive studies being made currently by Cocke and Strimple. It is extremely doubtful that the horizon producing *A. supplantus* is the Hogshooter Formation or its equivalent horizon in Kansas.

Occurrence.—Holotype UNSM 10417, collected from the "Hogshooter" Formation (probably Winterset), Kansas City Group, Missourian Stage (Upper Pennsylvanian), C, N ½, sec. 2, T. 35 S., R. 16 E., Montgomery County, Kansas.

Family ULOCRINIDAE Moore & Strimple, 1973

Genus ULOCRINUS Miller & Gurley, 1890

Type Species.—Ulocrinus buttsi Miller & Gurley, 1890, p. 6.

ULOCRINUS sp. cf. U. BUTTSI Miller & Gurley, 1890

Remarks.—An infrabasal circlet was collected from the Merriam (=Meadow) Limestone exposed in the SE ¼, SE ¼, sec. 17, T. 27 S., R. 16 E., Montgomery County, Kansas. It is comparable to the specimen reported by Strimple (1969, p. 65) collected from the Stoner Limestone Member, Stanton Formation. The specimen described by Strimple was recovered from a drill core hole, Kansas Survey Hole G, SE ¼, SW ¼, SW ¼, sec. 33, T. 30 S., R. 14 E., Wilson County, Kansas.

Material Studied.—Hypotype UNSM 10475.

Superfamily LOPHOCRINACEA Bather, 1899

Family LAUDONOCRINIDAE Moore & Strimple, 1973

Genus LAUDONOCRINUS Moore & Plummer, 1940

Type Species.—*Hydreionocrinus subsinuatus* Miller & Gurley, 1893, p. 40-41, pl. 6, fig. 11-14.

Other Species Included.—*Laudonocrinus cucullus* Moore & Plummer, 1940; *Laudonocrinus catillus* Moore & Plummer, 1940; *Laudonocrinus arrectus* Moore & Plummer, 1940.

Diagnosis.—See Moore & Plummer, 1940, p. 40-41.

Occurrence.—Middle Pennsylvanian (Demoinesian)-Upper Pennsylvanian (Missourian), USA (Texas, Oklahoma, Kansas, Nebraska, Illinois).

LAUDONOCRINUS SUBSINUATUS (Miller & Gurley, 1893)

Figure 4, *8-10*

Hydreionocrinus subsinuatus Miller & Gurley, 1893, p. 40-41, pl. 6, fig. 11-14; Beede, 1900, p. 43-45, pl. 8, fig. 14.

Laudonocrinus subsinuatus Moore & Plummer, 1940, p. 174-175, pl. 6, fig. 6; Shimer & Shrock, 1944, p. 165, pl. 62, fig. 10; pl. 64, fig. 10; Strimple & Moore, 1971, p. 20, pl. 9, fig. 1a, b, 3; Strimple & Moore, 1971, p. 19, fig. 6, 5.

Remarks.—*Laudonocrinus subsinuatus* appears to be confined to rocks of Missourian age. Its southernmost known occurrences are in lower Missourian rocks, whereas in Nebraska this species occurs in upper Missourian (Stanton) rocks. *Laudonocrinus subsinuatus* appears to be most similar to *L. cucullus,* from which it may have been derived. *L. cucullus* is ornamented with closely spaced, fine granules, whereas *L. subsinuatus* is smooth. *L. catillus* is characterized by narrow radial facets and an angulation at the interradial sutures. *L. arrectus* has straighter sides of the cup and much wider radial facets.

Strimple & Moore (1971, p. 20) indicated that *Laudonocrinus cucullus* and *L. catillus* may belong to another genus. The nature of the bases of these species, known only from dorsal cups, suggests that they may belong in *Metaperimestocrinus.*

Occurrence.—Ladore shale, Kansas City Group, Missourian Stage (Upper Pennsylvanian), NW ¼, sec. 1, T. 20 S., R. 24 E., 3 miles east of La Cygne, Linn County, Kansas. "Hogshooter" (probably Winterset) Formation, N ½, sec. 2, T. 35 S., R. 16 E., Montgomery County, Kansas.

Material Studied.—Hypotypes UNSM 10423 and UNSM 10424.

Genus BATHRONOCRINUS Strimple, 1962

Type Species.—*Bathronocrinus turioformis* Strimple, 1962, p. 37-38, pl. 1, fig. 15-18.

Other Species Included.—*Hypermorphocrinus magnospinosus* Arendt, 1968, p. 529-530, pl. 1; *Hydreionocrinus deweyensis* Strimple, 1939, p. 14-15, pl. 2, fig. 13-17; *Bathronocrinus wolfriverensis* Pabian & Strimple, 1974, p. 281-282, pl. 35, fig. 1-4, table 23.

Diagnosis.—See Strimple, 1962, p. 37-38.

Occurrence.—Middle Pennsylvanian (Demoinesian)-Upper Pennsylvanian (Missourian, Virgilian), USA (Oklahoma, Nebraska); Lower Permian, USSR.

BATHRONOCRINUS sp. cf. B. TURIOFORMIS Strimple, 1962

Figure 5, *1-3*

cf. *Bathronocrinus turioformis* Strimple, 1962, p. 38, pl. 1, fig. 15-18.

Remarks.—The specimen at hand is a dorsal cup from an immature individual. It has the sharp notches between the radius (*cf. B. turioformis)* though the anal plates do not form the broad, posteriorly situated depressions as they do in *B. turioformis;* thus, the dorsal cup of the specimen is pentagonal rather than hexagonal in outline.

Material Studied.—Hypotype UNSM 10448, collected from the Wann Formation, Ochelata Group, Missourian Stage (Upper Pennsylvanian) exposed at The Mound, west edge of Bartlesville, Oklahoma.

Superfamily TEXACRINACEA Strimple, 1961

Family CYMBIOCRINIDAE Strimple & Watkins, 1969

Genus ALLOSOCRINUS Strimple, 1949

Type Species.—*Allosocrinus bronaughi* Strimple, 1949, p. 18-19, pl. 4, fig. 1-4.

Other Species Included.—*Allosocrinus porus* Strimple, 1951; *Allosocrinus libratus* Strimple, 1961, p. 105.

Diagnosis.—See Strimple & Moore, 1971, p. 27.

Occurrence.—Middle Pennsylvanian (Demoinesian)-Upper Pennsylvanian (Virgilian), USA (Oklahoma, Kansas, Nebraska, Illinois).

ALLOSOCRINUS BRONAUGHI Strimple, 1949

Figure 5, *4-6*

Allosocrinus bronaughi Strimple, 1949, p. 18-19, pl. 4, fig. 1-4; Strimple & Moore, 1971, p. 27-28, fig. 6, *1*; pl. 8, fig. 5.

Remarks.—The specimen studied has slightly finer granular ornamentation than the figured holotype of *Allosocrinus bronaughi;* however, it does not differ significantly enough from the holotype to justify erection of either a new species or subspecies. Except for being somewhat smaller and having slightly more tumid basal plates, the specimen closely resembles *Allosocrinus* sp. *cf. A. bronaughi,* from the Ervine Creek Limestone (Virgilian) of Nebraska, reported by Pabian and Strimple (1974, p. 262-263, text-fig. 2a-c).

Allosocrinus bronaughi was described from the Wann Formation (Missourian) exposed at Ochelata, Oklahoma, and at The Mound and "Airport Road" cut west of Bartlesville, Oklahoma. *A. bronaughi* has also been reported from the La Salle Limestone (Missourian) of Illinois, and Eudora Shale (Missourian) of Southern Kansas, suggesting all of these rock units are approximately the same age.

Material Studied.—Hypotype UNSM 10414, Eudora Shale Member, Stanton Formation, Lansing Group, Missourian Stage (Upper Pennsylvanian), NE ¼, sec. 35, T. 32 S., R. 14 E., Montgomery County, Kansas.

Superfamily ERISOCRINACEA Wachsmuth & Springer, 1886

Family CATACRINIDAE Knapp, 1969

Genus DELOCRINUS Miller & Gurley, 1890

Type Species.—*Poteriocrinus hemisphericus* Shumard, in Shumard & Swallow, 1858, p. 221.

DELOCRINUS HEMISPHERICUS (Shumard, 1858)

Figure 5, *7-9*

For synonymies, see p. 21.

Remarks.—*Delocrinus hemisphericus* is distributed throughout Missourian and Lower Virgilian rocks of the Mid-Continent region, having been reported from Texas, Oklahoma, Kansas, Missouri, Nebraska, and Iowa. It appears to have given rise to *Delocrinus brownvillensis,* the latter species developing by shortening of the primibrachials and developing a more paraboloid-shaped dorsal cup. *D. vulgatus* has short primibrachials and a more conical cup.

Material Studied.—Hypotype UNSM 10413, Eudora Shale Member, Stanton Formation, Kansas City Group, Missourian Stage (Upper Pennsylvanian), NE ¼, sec. 35, T. 32 S., R. 14 E., Montgomery County, Kansas. Hypotype UNSM 10465, Plattsmouth Limestone Member, Oread Formation, Shawnee Group, Virgilian Stage (Upper Pennsylvanian), approx. NW ¼, sec. 21, T. 12 S., R. 19 E., Douglas County, Kansas. Hypotype UNSM 10432, Weston Shale, Pedee Group, Virgilian Stage (Upper Pennsylvanian), approx. NW ¼, sec. 21, T. 12 S., R. 19 E., Douglas County, Kansas. Hypotype UNSM 10432, Weston Shale, Pedee Group, Virgilian Stage (Upper Pennsylvanian), approx. NE ¼, sec. 6, T. 32 S., R. 14 E., Montgomery County, Kansas. Hypotypes UNSM 10430-10431, Wann (=Stanton) Formation, Lansing Group, Missourian Stage (Upper Pennsylvanian), The Mound, SE ¼, sec. 3, T. 26 N., R. 12 E., Osage County, Oklahoma. Hypotype, UNSM 10433, UNSM 10434, "Hogshooter" (=Dennis) Formation,

FIG. 5. *Bathronocrinus* sp. *cf. B. turioformis* Strimple *(1-3)*; *Allosocrinus bronaughi* Strimple *(4-6)*; *Delocrinus hemisphericus* (Shumard) *(7-9)*; *Delocrinus brownvillensis* Strimple *(10-12)*; *Graffhamicrinus aristatus* (Strimple) *(13-15)*.——*1-3*. *B.* sp. *cf. B. turioformis* Strimple; hypotype, UNSM 10448, ventral, dorsal, and posterior views, ×4.——*4-6*. *A.* sp. *cf. A. bronaughi* Strimple; hypotype, UNSM 10414; *4,5,* dorsal and posterior views, ×3; *6,* section of anal tube found associated with UNSM 10414, ×3.——*7-9*. *D. hemisphericus* (Shumard); hypotype, UNSM 10465, ventral, dorsal, and posterior views, ×2.——*10-12*. *D. brownvillensis* Strimple; hypotype, UNSM 10419, ventral, posterior, and dorsal views, ×2.——*13-15*. *G. aristatus* Strimple; hypotype, UNSM 10450; ventral, dorsal, and posterior views, ×3.

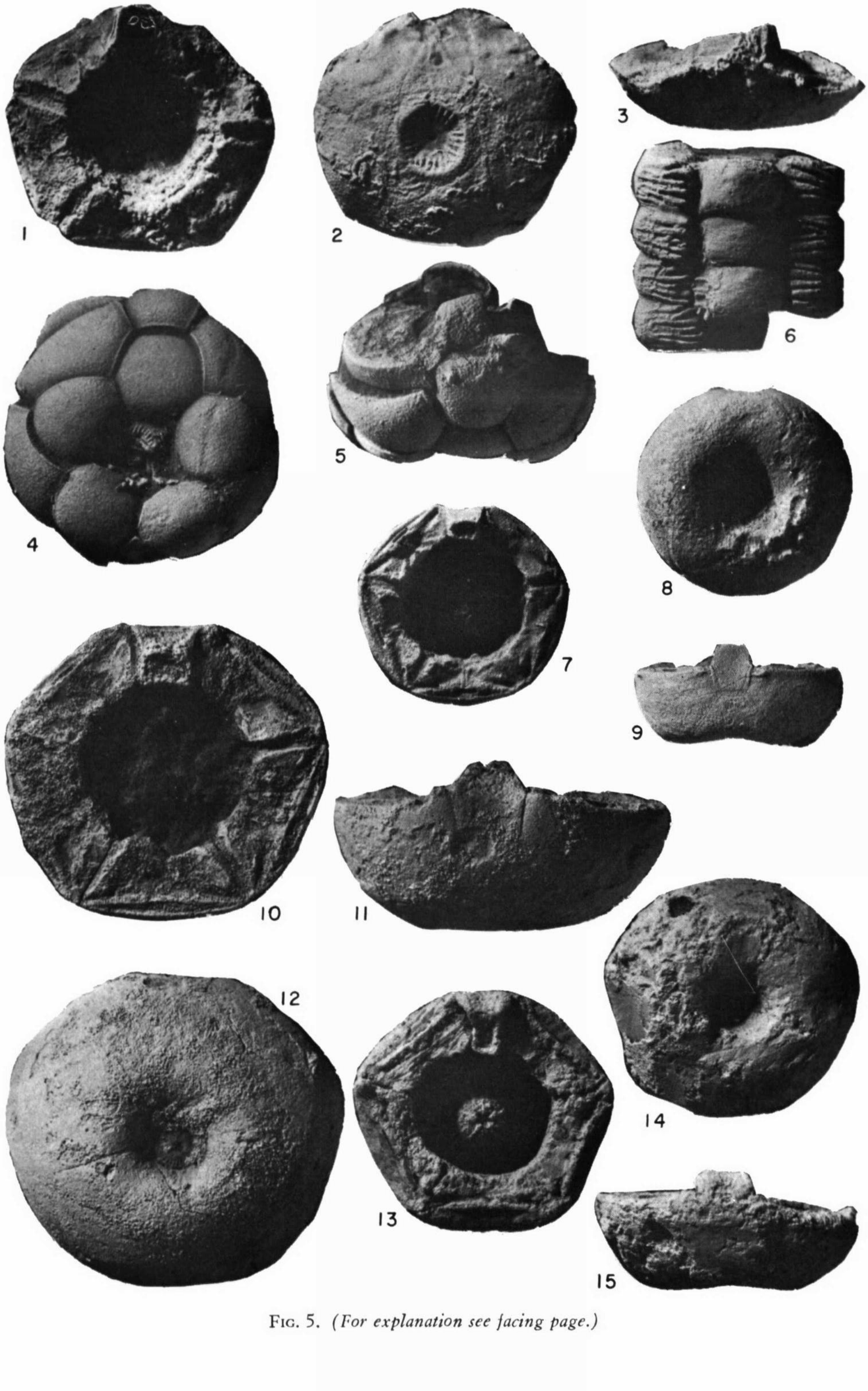

Fig. 5. *(For explanation see facing page.)*

Kansas City Group, Missouri Series (Upper Pennsylvanian), approx. E ½, sec. 9, T. 26 N., R. 14 E., Washington County, Oklahoma. Hypotypes UNSM 10426-UNSM 10429, "Lost City" Limestone [=Hogshooter (=Dennis)] Limestone, probably from Gould's "Lost City" type locality, Lost City, Oklahoma. Hypotype UNSM 10444, Weston Shale, NW ¼, sec. 13, T. 53 N., R. 35 W., south of Weston, Platte County, Missouri. Hypotypes UNSM 10451-UNSM 10454, Haskell Member, Cass Formation, Douglas Group, Virgilian Stage (Upper Pennsylvanian), NE ¼, NE ¼, sec. 30, T. 12 N., R. 12 E., Cass County, Nebraska. Hypotype UNSM 10469, Calhoun Shale, Virgilian Stage (Upper Pennsylvanian), NE ¼, sec. 7, T. 30 S., R. 11 E., Elk County, Kansas.

DELOCRINUS BROWNVILLENSIS Strimple, 1949

Figure 5, *10-12*

Delocrinus brownvillensis Strimple, 1949, p. 22-23, pl. 4, fig. 1, 4; 1962, p. 109-110; Pabian & Strimple, 1973, p. 17-20, fig. 1, 2, table 1.

Delocrinus vulgatus Pabian & Strimple, 1973, p. 17-20, fig. 1a-c; Moore & Plummer *(partim)*, 1939, p. 286-288, pl. 18, fig. 1a-c, fig. 2, 2a, b.

Remarks.—Delocrinus brownvillensis appears to be closely related to *Delocrinus vulgatus,* the major difference being in the shape of the cup, the former being more ellipsoidal in cross section through the midsection of the A ray and the posterior interray. The present collections indicate that the largest adults of *D. vulgatus* became considerably larger than those of *D. brownvillensis. Delocrinus brownvillensis* may be a late form in a lineage including *D. hemisphericus* and *D. vulgatus.*

The specimen under study shows evidence of having been weathered, the cup having an almost "burned" appearance. The cup appears to have been strongly oxidized.

Material Studied.—Hypotype UNSM 10419, Jim Creek Member, Root Formation, Wabaunsee Group, Virgilian Stage (Upper Pennsylvanian), approximate SE ¼, sec. 30, T. 11 S., R. 12 E., Wabaunsee County, Kansas.

DELOCRINUS EXTRANEOUS Strimple, 1949

Delocrinus extraneous Strimple, 1949, p. 25-26, pl. 7, fig. 1-3.

Remarks.—This species is characterized by its low, nearly discoidal cup with a broad, shallow basal concavity. Such a species may have given rise to *Pyndaxocrinus* by developing a flat base. *D. extraneous* appears most similar to *D. hemisphericus* from which it differs by having a lower cup and a broader, more shallow basal concavity.

Material Studied.—Hypotypes UNSM 10463, UNSM 10464, Plattsmouth Limestone, Oread Formation, Shawnee Group, Virgilian Stage (Upper Pennsylvanian), NW ¼, sec. 21, T. 12 S., R. 19 E., Douglas County, Kansas.

DELOCRINUS VULGATUS Moore & Plummer, 1940

See Pabian & Strimple, 1974, p. 266, for synonymy to date.

Material Studied.—One partial dorsal cup, hypotype, UNSM 10470, Calhoun Shale, Shawnee Group, Virgilian Stage (Upper Pennsylvanian), NE ¼, sec. 7, T. 30 S., R. 11 E., Elk County, Kansas.

Family DIPHUICRINIDAE Strimple & Knapp, 1966

Genus GRAFFHAMICRINUS Strimple, 1961

Type Species.—Graffhamicrinus acutus Strimple, 1961, p. 123-127, text-fig. 22a, b; pl. 10, fig. 4-8; pl. 12, fig. 4-6; pl. 15, fig. 6; pl. 19, fig. 2.

Diagnosis.—See Strimple, 1961, p. 123-127.

Remarks.—The oldest representative of *Graffhamicrinus* is *G. antiquus* from the Atokan of Texas, which has a low-bowl cup with an extremely deep basal concavity. *G. waughi* from the Permian (Big Blue) of Kansas is the youngest known representative, which also has a low-bowl cup and deep, narrow basal concavity. More precisely, the dorsal cups of the youngest and oldest representatives of this genus are more alike than the cups of some of the intervening species.

Graffhamicrinus stullensis (Strimple) has a low-bowl cup with a broad, shallow basal concavity as does *G. boellstorffi* Pabian & Strimple. Both species have considerable ornamentation, the latter being the coarser. One "lineage" of *G. stullensis* exhibits a tendency toward a deformity in the anterior interrays (Pabian & Strimple, 1974, p. 272, pl. 33, fig. 4, 5; this paper, p. 32, Fig. 15,*1-3*). It appears that there may be several evolutionary lineages within *Graffhamicrinus* including a *G. antiquus-G. waughi* lineage through some intermediate forms such as *G. magnificus* and *G. tetraspinosus,* and a *G. stullensis-G. boellstorffi* lineage.

Occurrence.—Middle Pennsylvanian (Atokan) through Lower Permian (Big Blue, =Wolfcampian), USA (Texas, Oklahoma, Kansas, Nebraska, Iowa, Ohio, West Virginia).

GRAFFHAMICRINUS ACUTUS Strimple, 1961

Graffhamicrinus acutus Strimple, 1961, p. 123-127, text-fig. 22a, b; pl. 10, fig. 4-8; pl. 12, fig. 4-6; pl. 13, fig. 7, pl. 15, fig. 6; pl. 19, fig. 2.

Remarks.—At first glance the specimen appears to have a smooth cup and so assignable to *Delocrinus* or some other allied genus. However, much of the cup is weathered and worn smooth, and unweathered portions of the cup appear to have an outer layer of calcite on which the nodes, ridges, and tubercles have developed. The arms are best preserved on the *A* and *E* rays, whereas the radials are best preserved on the *B* and *C* rays.

Material Studied.—Topotype UNSM 10467, collected from the ?Holdenville Formation, Desmoinesian Stage (Middle Pennsylvanian), NE ¼, sec. 24, T. 15 N., R. 11 E., Okmulgee County, Oklahoma.

GRAFFHAMICRINUS SUBCORONATUS Moore & Plummer, 1940

Delocrinus subcoronatus Moore & Plummer, 1940, p. 280-282, pl. 17, fig. 1.

Graffhamicrinus subcoronatus Pabian & Strimple, 1974, p. 271, pl. 37, fig. 9-11.

Remarks.—This species appears to have a short range-zone, confined to uppermost Missourian and lowermost Virgilian rocks. It may represent a short-ranged, ecological adaptation to the changing conditions between Missourian and Virgilian time.

Material Studied.—Hypotypes UNSM 10455-UNSM 10457, Haskell Member, Cass Formation, Douglas Group, Virgilian Stage (Upper Pennsylvanian), NE ¼, NE ¼, sec. 30, T. 12 N., R. 12 E., Cass County, Nebraska. Hypotype UNSM 10481, "Hogshooter" (probably Winterset) Formation, Kansas City Group, Missourian Stage (Upper Pennsylvanian), C, N ½, sec. 2, T. 35 S., R. 16 E., Montgomery County, Kansas.

GRAFFHAMICRINUS ARISTATUS Strimple, 1949

Figure 5, *13-15*

Delocrinus aristatus Strimple, 1949, p. 18-19, pl. 3, fig. 18-21.

Graffhamicrinus aristatus Strimple, 1961, p. 124.

Remarks.—*Graffhamicrinus aristatus* appears to be a very primitive representative of this genus. The radial facets, contour of the cup, and attitude of the anal plate strongly suggest a relationship to *Diphuicrinus* Moore & Plummer.

Material Studied.—Topotype UNSM 10450, Lester Limestone Member, Dornick Hills Formation, Atokan Stage (Middle Pennsylvanian), NE ¼, SW ¼, sec. 23, T. 5 S., R. 1 E., Carter County, Oklahoma.

GRAFFHAMICRINUS MAGNIFICUS (Strimple, 1947)

Figure 6, *1*

Delocrinus magnificus Strimple, 1947, p. 3-5, pl. 1, fig. 1-4, pl. 2, fig. 1.

Graffhamicrinus magnificus Strimple, p. 998, 1971, pl. 123, fig. 5; Pabian & Strimple, 1974, p. 270-271, pl. 33, fig. 1-3.

Remarks.—The specimen at hand is a topotype collected by Allen Graffham. It is a well-preserved, slightly crushed crown.

Material Studied.—UNSM 561, Haskell Limestone, Cass Formation, Douglas Group, Virgilian Stage (Upper Pennsylvanian), exposed near Homewood, Kansas.

Family ERISOCRINIDAE Wachsmuth & Springer, 1886

Genus ERISOCRINUS Meek & Worthen, 1865

Type Species.—*Erisocrinus typus* Meek & Worthen, 1865, p. 174.

Occurrence.—Upper Pennsylvanian (Missourian-Virgilian), USA (Texas, Oklahoma, Kansas, Nebraska, Iowa, Illinois); Lower Permian (Wolfcampian), USA (Nevada).

ERISOCRINUS TYPUS Meek & Worthen, 1865

Figure 6, *2, 3*

Erisocrinus typus Meek & Worthen, 1865, p. 174; 1873, p. 561, pl. 24, fig. 6.

Remarks.—The material included here is intended to provide additional geographic and stratigraphic data on the distribution of this species.

Material Studied.—Hypotype UNSM 10415, Eudora Shale Member, Stanton Formation, Lansing Group, Missourian Stage (Upper Pennsylvanian), NE ¼, sec. 35, T. 32 S., R. 14 E., Montgomery County, Kansas. Hypotypes UNSM 10435-UNSM 10437, Merriam (= Meadow) Limestone, Plattsburg Formation, Lansing Group, Missourian Stage (Upper Pennsylvanian), SW ¼, NW ¼, sec. 24, T. 31 S., R. 15 E., Montgomery County, Kansas. Hypotypes UNSM 10438-UNSM 10441, Spring Hill Limestone, Plattsburg Formation, Lansing Group, Missourian Stage (Upper Pennsylvanian), SE ¼, SE ¼, sec. 17, T. 27 S., R. 16 E., Wilson County, Kansas. Hypotype UNSM 10442, "Hogshooter" (= Winterset) Limestone, Gould's "Lost City" Limestone type

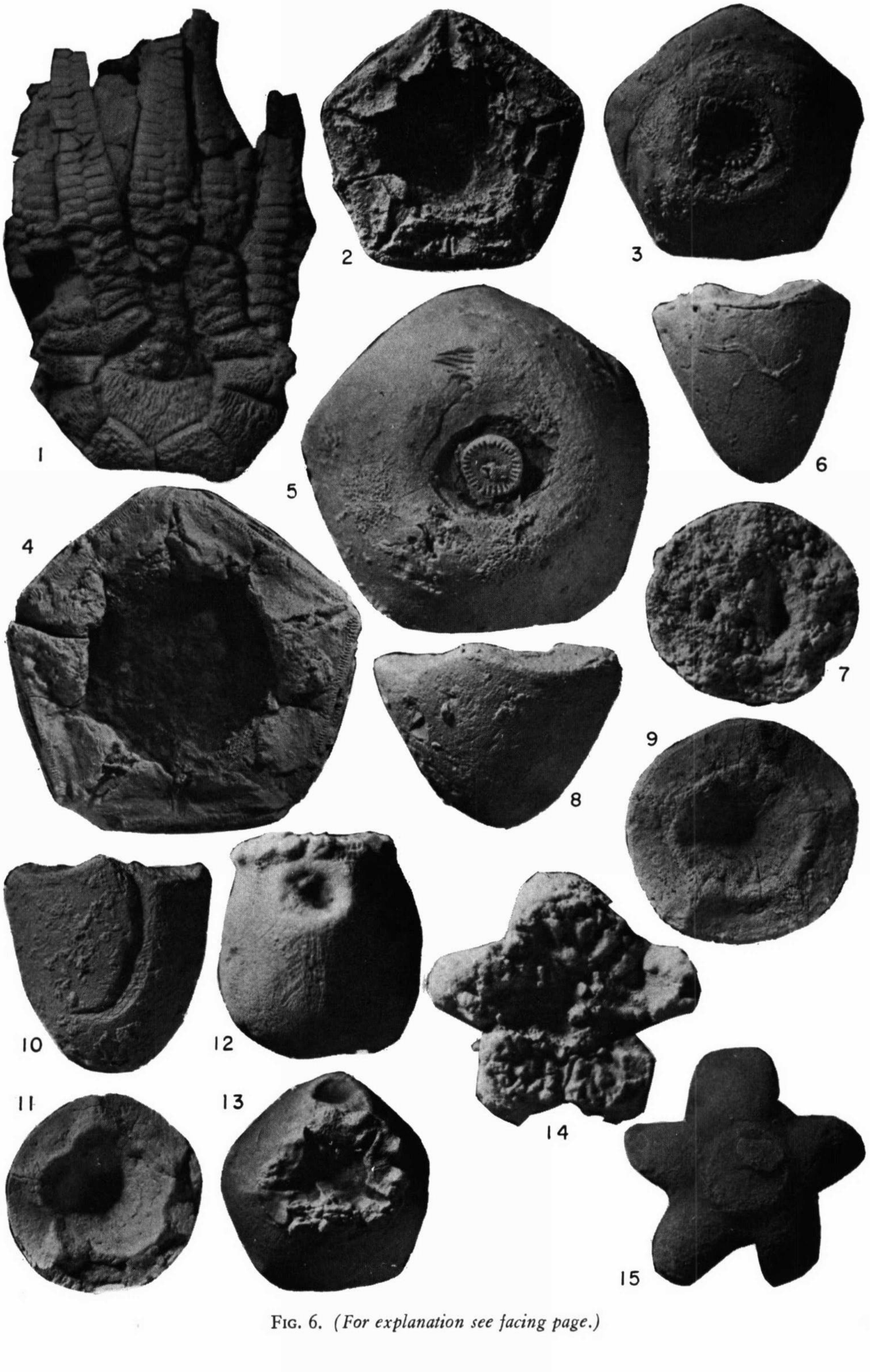

Fig. 6. *(For explanation see facing page.)*

locality, 2 miles west of Tulsa, Tulsa County, Oklahoma. Hypotype UNSM 10460, Cass Member, Haskell Formation, Douglas Group, Virgilian Stage (Upper Pennsylvanian), NE ¼, NE ¼, sec. 30, T. 12 N., R. 12 E., Cass County, Nebraska.

ERISOCRINUS OBOVATUS Moore & Plummer, 1940
Figure 6, *4, 5*

Paradelocrinus obovatus Moore & Plummer, 1940, p. 326-328, text-fig. 66; pl. 15, fig. 9, pl. 20, fig. 4.
Erisocrinus obovatus Strimple & Watkins, 1969, p. 180-182.
Parerisocrinus obovatus Knapp, 1969, p. 358, text-fig. 13; Pabian & Strimple, 1973, p. 14-15, pl. 7, fig. 10-11.

Remarks.—Current collections indicate that *Erisocrinus obovatus* is confined to rocks of early Missourian age. Because of this relatively close stratigraphic confinement, and the ease with which the species may be identified, its use as an index fossil should become quite important.

Material Studied.—Specimens currently studied were collected from the "Hogshooter" (=Winterset) Limestone, Dennis Formation, Kansas City Group, Missourian Stage (Upper Pennsylvanian). Hypotypes UNSM 10420, UNSM 10421, and UNSM 10422 were collected from the C, N ½, sec. 2, T. 32 S., R. 16 E., Montgomery County, Kansas. Hypotypes UNSM 10485, UNSM 10486, and UNSM 10487 were collected from the E ½, sec. 9, T. 26 N., R. 14 E., Nowata County, Oklahoma.

Superfamily APOGRAPHIOCRINACEA Moore & Laudon, 1943

Family APOGRAPHIOCRINIDAE Moore & Laudon, 1943

Genue APOGRAPHIOCRINUS Moore & Plummer, 1940

Type Species.—*Apographiocrinus typicalis* Moore & Plummer, 1940, p. 115-123, text-fig. 14-16; pl. 3, fig. 4, 5.

Other Species Included.—*Apographiocrinus exculptus* Moore & Plummer, 1940; *A. facetus* Moore & Plummer, 1940; *A. calycinus* Moore & Plummer, 1940; *A. decoratus* Moore & Plummer, 1940; *A. wolfcampensis* Moore & Plummer, 1940; *A. rotundus* Strimple, 1948; *A. obtusus* Strimple, 1948; *A. quietus* Strimple, 1948; *A. angulatus* Strimple, 1948; *A. arcuatus* Strimple, 1949; *A. virgilicus* Pabian & Strimple, 1974.

Diagnosis.—See Moore & Plummer, 1940, p. 115-123.

Occurrence.—Middle Pennsylvanian (Desmoinesian)-Upper Pennsylvanian (Virgilian), Lower Permian (Wolfcampian), USA (Texas, Oklahoma, Kansas, Nebraska, Iowa, Missouri, Illinois, Michigan).

APOGRAPHIOCRINUS TYPICALIS Moore & Plummer, 1940

Apographiocrinus typicalis Moore & Plummer, 1940, p. 118, pl. 3, fig. 4, 5.

Remarks.—The specimens studied add only to our knowledge of the geographic and stratigraphic distribution of this species.

Material Studied.—Hypotype UNSM 10471, P.W.A. Limestone. Hypotypes UNSM 10488 and UNSM 10489, Cement City Limestone, Drum Formation, Kansas City Group, Missourian Stage (Upper Pennsylvanian), Kansas City Water Works excavations, north of Kansas City, Missouri. Hypotype, UNSM 10472 and UNSM 10473, Merriam (=Meadow Limestone), Plattsburg Formation, Lansing Group, Missourian Stage (Upper Pennsylvanian), SW ¼, NW ¼, sec. 24, T. 31 S., R. 15 E., Montgomery County, Kansas.

Superfamily AGASSIZOCRINACEA S. A. Miller, 1890

Family AGASSIZOCRINIDAE S. A. Miller, 1890

Genus PARAGASSIZOCRINUS Moore & Plummer, 1940

FIG. 6. *Graffhamicrinus magnificus* Strimple *(1)*; *Erisocrinus typus* Meek & Worthen *(2,3)*; *E. obovatus* Moore & Plummer *(4,5)*; *Paragassizocrinus tarri* Strimple *(6-9)*; *Paragassizocrinus* sp. *(10,11)*; *Lecythiocrinus olliculaeformis* White *(12,13)*; *Isoallagecrinus strimplei* Kirk *(14,15)*.——*1*. *G. magnificus* Strimple; topotype, UNSM 561, anterior view of crown, ×1.——*2,3*. *E. typus* Meek & Worthen; hypotype, UNSM 10435, ventral and dorsal views, ×4.——*4,5*. *E. obovatus* Moore & Plummer; hypotype, UNSM 10422, ventral and dorsal views, ×2.——*6-9*. *P. tarri* Strimple; *6,7*, hypotype, UNSM 10484, lateral and ventral views of infrabasal cone, ×3; *8,9*, hypotype, UNSM 10482, lateral and ventral views of infrabasal cone, ×3.——*10,11*. *P.* sp.; hypotype, UNSM 10483, lateral and ventral views of infrabasal cone, ×3 (note: deep cut on side of cone).——*12,13*. *L. olliculaeformis* White; hypotype, UNSM 10443, posterior and ventral views, ×3.——*14,15*. *I. strimplei* (Kirk), hypotype, UNSM 10425; ventral and dorsal views, ×5.

Type Species.—*Agassizocrinus tarri* Strimple, 1938, p. 10-11, pl. 2, fig. 7, 10, 13.

Other Species Included.—*Agassizocrinus mcguirei* Strimple, 1939; *Paragassizocrinus assymetricus* Strimple, 1960; *P. elongatus* Strimple, 1960; *P. turris* Strimple, 1960; *P. deltoideus* Strimple, 1960; *P. hoodi* Strimple, 1960; *P. disculus* Strimple, 1960; *P. springeri* Strimple, 1960; *P. elevatus* Strimple, 1961; *P. bulbosus* Strimple, 1961; *P. atoka* Strimple & Blythe, 1960; *P. altus* Strimple & Watkins, 1969; *P. kendrickensis* Strimple & Knapp, 1966; *Agassizocrinus carbonarius* Worthen, 1873; *Henanobasis coffeyvillensis* Moore, 1939.

Occurrence.—Lower Pennsylvanian (Morrowan)-Upper Pennsylvanian (Missourian), USA (Texas, Arkansas, Oklahoma, Kentucky, Kansas, Illinois).

PARAGASSIZOCRINUS TARRI Strimple, 1939

Figure 6, *6-9*

Agassizocrinus tarri Strimple, 1939, p. 10, pl. 2, fig. 7, 10, 13.

Petschoracrinus tarri Yakovlev, 1939, p. 832.

Paragassizocrinus tarri Moore & Plummer, 1940, p. 345-352, text-fig. 68; pl. 1, fig. 6, pl. 16, fig. 9; Strimple, 1960, p. 9-13, pl. 2, fig. 4, 5, 12, 13.

Remarks.—Two infrabasal circlets are referred to *Paragassizocrinus tarri,* one reportedly from the Lost City Member, Hogshooter Formation in Tulsa County, Oklahoma and the other reportedly from the "Hogshooter Formation" in Montgomery County, Kansas. One of us (Strimple) has collected extensively in the Hogshooter Formation, in the "Lost City" area southwest of Tulsa, Tulsa County, Oklahoma, without recovering any infrabasal cones of *Paragassizocrinus,* although they are not uncommon in molluscan faunas of the overlying Nellie Bly Formation, which is also exposed in the same general area. The preservation of the specimen at hand suggests a marly shale matrix and we are inclined to believe it may have been recovered from the Nellie Bly Formation rather than the Hogshooter Formation. The Lost City Member, Hogshooter Formation, is a massive limestone in the area. The "Hogshooter Formation" is not positively identified in Montgomery County, Kansas, and is being investigated by Cocke and Strimple at the present time.

The Tulsa County specimen is larger than typical for the species. The Montgomery County infrabasal cone is proportionately taller. Without several specimens available it is not possible to arrive at a norm.

Material Studied.—Hypotype UNSM 10482, ?Nellie Bly Formation, Gould's "Lost City" type locality 2 miles southwest of Tulsa, Tulsa County, Oklahoma. Hypotype UNSM 10484, "Hogshooter" (=Winterset) Limestone, Kansas City Group, Missourian Stage (Upper Pennsylvanian), N ½, sec. 2, T. 32 S., R. 16 E., Montgomery County, Kansas. The holotype is from the Wann Formation south of Bartlesville, Washington County, Oklahoma.

PARAGASSIZOCRINUS sp.

Figure 6, *10, 11*

Remarks.—A single infrabasal cone from the Iatan Limestone is of medium height with a truncated base (see Strimple, 1960, text-fig. 1, Group B II). Most species falling in this category ("bullet-shaped") have subhorizontal upper facets that have thick projections at interbasal positions (e.g., *Paragassizocrinus turris* Strimple, 1961), whereas the present specimen has sharp ridges and facets like *P. tarri* (Strimple, 1938). If comparable material is subsequently found it might warrant speciation.

Material Studied.—Hypotype UNSM 10483, Iatan Limestone, Pedee Group, Missourian Stage (Upper Pennsylvanian), brick yard at Fort Leavenworth, Leavenworth County, Kansas.

Suborder CYATHOCRININA Bather, 1899

Superfamily CODIACRINACEA Bather, 1890

Family CODIACRINIDAE Bather, 1890

Subfamily CODIACRININAE Bather, 1890

Genus LECYTHIOCRINUS White, 1880

Type Species.—*Lecythiocrinus olliculaeformis* White, 1880, p. 257.

Other Species Included.—*Lecythiocrinus adamsi* Worthen, 1882; *L. urnaeformis* Strimple, 1939; *L. fusiformis* Strimple, 1949; *L. optimus* Strimple, 1951; *L. tubiformis* Strimple, 1951.

Diagnosis.—Dorsal cup cylindrical, rounded at base, and somewhat constricted at summit; three infrabasals; five hexagonal basals, five hexagonal radials; *C* and *D* radials separated below by an anal? opening that also indents the distal ends of the *CD* basal. Stem and arms unknown.

Occurrence.—Upper Pennsylvanian (Missourian), USA (southeastern Kansas, northeastern Oklahoma).

LECYTHIOCRINUS OLLICULAEFORMIS White, 1880
Figure 6, *12, 13*

Lecythiocrinus olliculaeformis White, 1880, p. 257; 1883, p. 124, pl. 35, fig. 2a, b; Wachsmuth & Springer, 1886, p. 152; Strimple, 1939, p. 18-19, pl. 3, fig. 5-7.

Remarks.—The holotype of *Lecythiocrinus olliculaeformis* is listed as having been collected from Upper Coal-Measure strata "30 miles west of Humboldt, Kansas." Some doubt is cast here as to the accuracy of the distance from Humboldt, Kansas, as given by White. Current data obtainable from collections indicates that *L. olliculaeformis* has been collected only from Wilson County, Kansas, and Washington and Osage Counties, Oklahoma. It is suggested here that White's specimen was collected in or near Wilson County.

Material Studied.—Hypotypes UNSM 10443-UNSM 10446 were collected from the Spring Hill Limestone, Plattsburg Formation, Lansing Group, Missourian Stage (Upper Pennsylvanian), exposed in the abandoned quarry south of Wilson County State Park, SE ¼, SE ¼, sec. 17, T. 27 S., R. 16 E., Wilson County, Kansas.

Order DISPARIDA Moore & Laudon, 1943

Superfamily ALLAGECRINACEA Carpenter & Etheridge, 1881

Family ALLAGECRINIDAE Carpenter & Etheridge, 1881

Genus ISOALLAGECRINUS Strimple, 1966

ISOALLAGECRINUS STRIMPLEI (Kirk, 1936)
Figure 6, *14, 15*

Allagecrinus strimplei Kirk, 1936, p. 162, text-fig. 1-10.
Isoallagecrinus strimplei Strimple, 1966, p. 104.

Remarks.—The specimen of *Isoallagecrinus strimplei* considered here has been weathered, probably in ancient times since the damaged portion was entirely enclosed in matrix. It is not uncommon to find crinoids deeply weathered, even those removed from freshly quarried rock (e.g., Pabian & Strimple, 1974, p. 269, p. 293). It is apparently a gerontic specimen of *I. strimplei,* which species has hitherto been known only from a calcareous shale at the base of the Dewey Limestone Formation in west central Washington County, Oklahoma. The Dewey Limestone has (see Moore, 1949, p. 97) been considered on occasion as equivalent to the Cement City Member of the Drum Formation, in Montgomery County, Kansas. One of us (Strimple) is not convinced they are identical.

Material Studied.—Hypotype UNSM 10425, Cement City Limestone, Drum Formation, Kansas City Group, Missouri Series (Upper Pennsylvanian), Kansas City Water Works excavations, North of Kansas City, Missouri.

REFERENCES

See composite list following Part 4.

PART 2

SOME CRINOIDS FROM THE COAL CREEK LIMESTONE (VIRGILIAN) OF IOWA, NEBRASKA, AND KANSAS

ABSTRACT

Thirty-eight crowns and dorsal cups indicate eleven species of inadunate crinoids representing seven families—Catacrinidae, Paradelocrinidae, Pirasocrinidae, Decadocrinidae, Cromyocrinidae, Galateacrinidae, and Scytalocrinidae—occur in the Coal Creek Limestone.

The material at hand provides a sample of crinoids from Middle Virgilian rocks; such crinoids have been previously known, but descriptions are sparse.

The anal sacs are preserved on specimens of *Paradelocrinus thurmanensis* Pabian & Strimple, new species; *Glaukosocrinus forneyi* Pabian & Strimple, new species; and *Triceracrinus topekensis* (Moore). *Scytalocrinus fremontensis* Pabian & Strimple, new species, is also described.

INTRODUCTION

The Coal Creek Limestone was named for Coal Creek north of Union, Nebraska (Condra, 1927, p. 52). It is the upper member of the Topeka Limestone Formation (Bennett, 1896). It is exposed in the Weeping Water Valley and at Jones Point, east of Union, in Cass County, and southeast of Dubois, in Richardson County, in Nebraska. It is subsurface in southeastern Richardson County.

The Coal Creek Limestone has been identified in quarries along the Missouri River in Fremont County in extreme southwestern Iowa by Hershey and others (1960, p. 15, fig. 5).

Moore (1949, p. 126, fig. 22, and p. 164) indicated that the Coal Creek Limestone formed the top of the Topeka Formation in northern Kansas. He further indicated that this unit could not be positively identified south of the Kansas River but that the "red limestone" in southern Kansas is probably its equivalent.

All the crinoids except two cups were collected from the Kaser Construction Company Quarry, situated in NW ¼, NW ¼, sec. 23, T. 70 N., R. 43 W., Fremont County, Iowa (Fig.

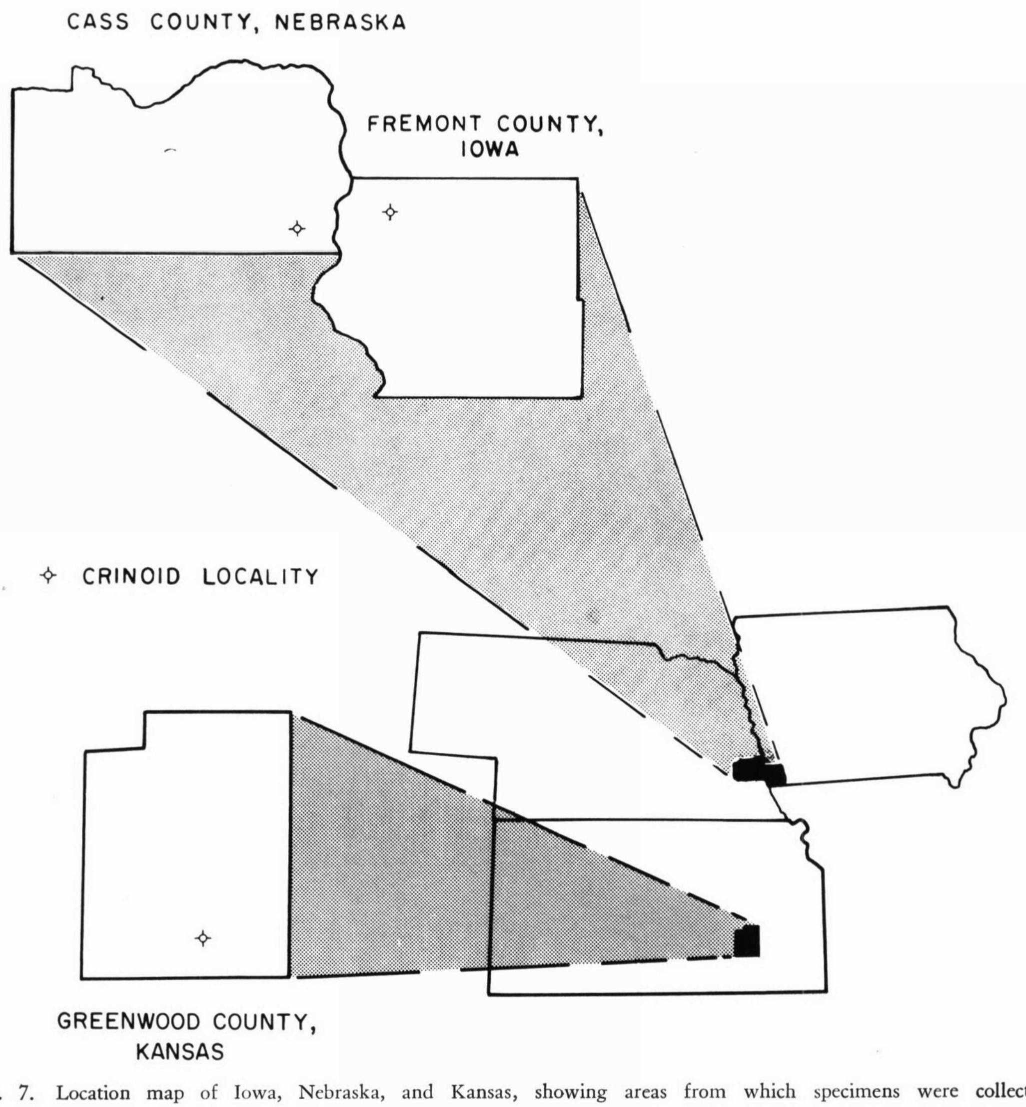

FIG. 7. Location map of Iowa, Nebraska, and Kansas, showing areas from which specimens were collected.

7). The lone Nebraska specimen was collected from the cut along the Missouri Pacific Railroad tracks near the SW ¼, SW ¼, NE ¼, sec. 14, T. 10 N., R. 14 E., Cass County, Nebraska (Fig. 7). This is adjacent to the Coal Creek type locality. The Kansas specimen was collected from the NE ¼, sec. 9, T. 27 S., R. 11 E., Greenwood County (Fig. 7).

Specimens are reposited in the University of Nebraska State Museum (UNSM) and the University of Iowa Paleontological Collections (SUI).

ACKNOWLEDGMENTS

The location maps and illustrations were prepared by Barbara Force, and the manuscript was typed by Doris Peabody and Mary Boyd, all of the Nebraska Conservation and Survey Division, University of Nebraska. Many of the specimens described herein were collected by Allen Graffham of Ardmore, Oklahoma, and W. D. White of Omaha, Nebraska. Kaser Construction Company of Des Moines, Iowa, allowed free access to quarry property.

SYSTEMATIC PALEONTOLOGY

Phylum ECHINODERMATA Laske, 1778

Subphylum PELMATOZOA Leuckart, 1848

Class CRINOIDEA Miller, 1821

Subclass INADUNATA Wachsmuth & Springer, 1885

Order CLADIDA Moore & Laudon, 1943

Family CATACRINIDAE Knapp, 1969

Genus DELOCRINUS Miller & Gurley, 1890

DELOCRINUS HEMISPHERICUS (Shumard, 1858)

Figure 8, *1-7*

Poteriocrinus hemisphericus Shumard, 1858, p. 221.
Scaphiocrinus hemisphericus Meek, 1872, p. 147, pl. V, fig. 1a, b, pl. VII, fig. 1a-c; Meek & Worthen, 1873, p. 561, pl. XXIV, fig. 5; Woodruff, 1907, p. 264, pl. 7, fig. 6.
Ceriocrinus hemisphericus Wachsmuth & Springer, 1886, p. 254; Keyes, 1894, p. 220, pl. XXVIII, fig. 2, 5; Beede, 1900, p. 34, pl. VI, fig. 5, 5b; Barbour, 1903, p. 127; Woodruff, 1907.
Delocrinus hemisphericus Miller & Gurley, 1890, p. 335, pl. 2, fig. 8-10; Moore & Strimple, 1970, p. 202-204, pl. 4.
Delocrinus subhemisphericus Moore & Plummer, 1940, p. 258-261, text-fig. 56, 57, pl. 11, fig. 4, pl. 20, fig. 3; Shimer & Shrock, 1944, p. 173, pl. 62, fig. 30, pl. 65, fig. 7; Strimple, 1947, p. 123-124, pl. IV, fig. 8-15; Strimple & Moore, 1971, p. 19-23, fig. 7, 8.

Emended Description.—(Emended to Shumard, 1858, p. 221.) *Delocrinus hemisphericus* is represented by seven partial crowns and nine dorsal cups. The arm-articulating facets are very well defined. The outer marginal ridge is sharp. There is a narrow, moderately deep outer-marginal furrow. The ligament pit is narrow and deep; it separates the finely denticulate transverse ridge into two distinct parts. The oblique ridges are fairly well defined. The lateral slope is about 45 degrees and the lateral ridge is very sharp. The muscle area slopes inward to a broad, shallow central pit, which is connected to a wide intramuscular notch by a short furrow.

There are five axillary primibrachials; they are slightly to moderately protruded on small individuals to sharply spinose on large individuals. The first secundibrachials are trapezoid-shaped, and the second are wedge-shaped. Subsequent brachials are arranged biserially. There are at least 35 biserially arranged segments on each arm; pinnules are observed on the inner facets.

Remarks.—The nature of the primibrachials changes somewhat during later growth stages. On the smaller specimens, the primibrachials are only slightly to moderately protruded, whereas on the larger individuals they form long spines.

The nature of the basal concavity of the specimens under scrutiny appears to be somewhat variable, ranging from deep and narrow to shallow and wide. Delocrinids from the Stull Shale of Nebraska and Kansas (the subject of another investigation) show similar variations in the nature of the basal concavity. This is a case of regressive evolution, the end product of which may be a species such as *Pyndaxocrinus separatus* (Strimple). A similar evolutionary trend may be observed in the Diphuicrinidae where *Graffhamicrinus* shows a tendency to evolve forms with shallow, broad bases such as *G. stullensis* (Strimple). In both cases, there appears to be two lineages, a conservative one whose forms retain deep, narrow basal concavities, and a regressive one whose forms evolve broad and shallow, or even flat bases.

Material Studied.—Hypotypes UNSM 8080, UNSM 10135-UNSM 10139, UNSM 10140-

UNSM 10144, UNSM 10146-UNSM 10151, UNSM 10171.

Family PARADELOCRINIDAE Knapp, 1969

Genus PARADELOCRINUS Moore & Plummer, 1938

PARADELOCRINUS THURMANENSIS Pabian & Strimple, new species

Figure 9, *2*; 10, *4*; 11, *1-3*

Description.—Paradelocrinus thurmanensis is based on a nearly complete, but damaged, crown and a cup. The cup is a low, basally impressed bowl. The infrabasal circlet is almost entirely covered with a small, round crenulated proximal columnal. The basal concavity is distinct but shallow and the proximal third of the pentagonal basals are included. The basal plane is in the medial portion of the basal circlet. The distal ends of the basals curve upward in a circular arc. The proximal tips of the five epaulette-shaped radials reach to the basal plane. The radials curve upward circularly and inward slightly near the summit of the cup.

Much of the radial articulating facet can be seen on one of the radials of the holotype crown, but are not well preserved on the paratype cup. The outer marginal ridge is a blunt structure. There is a narrow outer marginal furrow and a deep ligament pit. The transverse ridge is sharp. There is a steep lateral slope and sharp lateral ridge.

The five primibrachials are long, spinose elements followed by two, adjacent, rectangular secundibrachials. Succeeding tertibrachials, of which there may be as many as 35, are wedge-shaped, biserially arranged segments having facets for attachment of pinnules.

The anal sac is present. It appears to be a bulb near the area of attachment to the cup, being drawn out into a long, slender tube (Fig. 10,*4*).

The sutures between plates are distinct but not impressed. The sutures between adjacent radials and subjacent basals have articulated surfaces. The cup plates are smooth.

Measurements.—See Appendix I.

Remarks.—Because of the perfect pentameral symmetry and lack of primanal (anal *X*) plate, it is not possible to determine the position of the *A* radial or *CD* basal on the holotype. A small primanal is seen in the paratype. The arms taper to a point, unlike the arms of *Delocrinus,* which expand medially and then taper to a point.

The articulations on the suture faces may indicate specialized tissues, perhaps ligamental, as suggested by Strimple & Moore (1971, p. 19).

This species closely resembles several species of *Delocrinus, Erisocrinus,* and *Paradelocrinus.* The nature of the anal sac and arms (not expanding distally and then tapering) preclude placing considered species among the *Dipuicrinidae* or *Catacrinidae* and the concave base and long primibrachials indicate this species is not closely related to the *Erisocrinidae.* Its simplicity in morphology indicates it to be a late type of paradelocrinid. Except for the long, spinose primibrachials, the specimen closely resembles the specimen of *Paradelocrinus* sp. reported by Frederickson & Waddell (1960, p. 172-174).

Material Studied.—Holotype UNSM 10152 from Iowa location. Paratype UNSM 10418, NE ¼, sec. 9, T. 27 S., R. 11 E., Greenwood County, Kansas.

Genus ENDELOCRINUS Moore & Plummer, 1940

ENDELOCRINUS sp. cf. E. ROTUNDUS Strimple, 1963

Figure 8, *8-10*

cf. *Endelocrinus rotundus* Strimple, 1963, p. 71, pl. 12, fig. 5-8; Pabian & Strimple, 1974, p. 311.

Description.—Endelocrinus sp. *cf. E. rotundus* is represented by a single, basally impressed, medium bowl-shaped dorsal cup. The columnar cicatrix is round, crenulate, and has a round lumen; it makes a hemispherical depression in the infrabasal circlet. The infrabasal circlet is shaped like a ten-rayed star. The five basals are pentagonal. There is a deep cusp at the suture between adjacent basals. The proximal parts of the basals slope downward at about 30 degrees and the medial parts form the basal plane of the cup. The basals curve upward sharply and their distal

FIG. 8. *Delocrinus hemisphericus* Shumard *(1-7)*; *Endelocrinus* sp. *cf. E. rotundus* Strimple *(8-10)*.——*1-7. D. hemisphericus* Shumard; *1,2,* ventral and dorsal views of hypotype, UNSM 10144, ×3; *3, E*-ray view of hypotype, UNSM 10141, ×3; *4,* posterior view of hypotype, UNSM 10135, ×3; *5-7,* ventral, dorsal, and posterior views of hypotype, UNSM 10142.——*8-10. E.* sp. *cf. E. rotundus* Strimple, ventral, dorsal, and posterior views of hypotype, UNSM 10153, ×2.

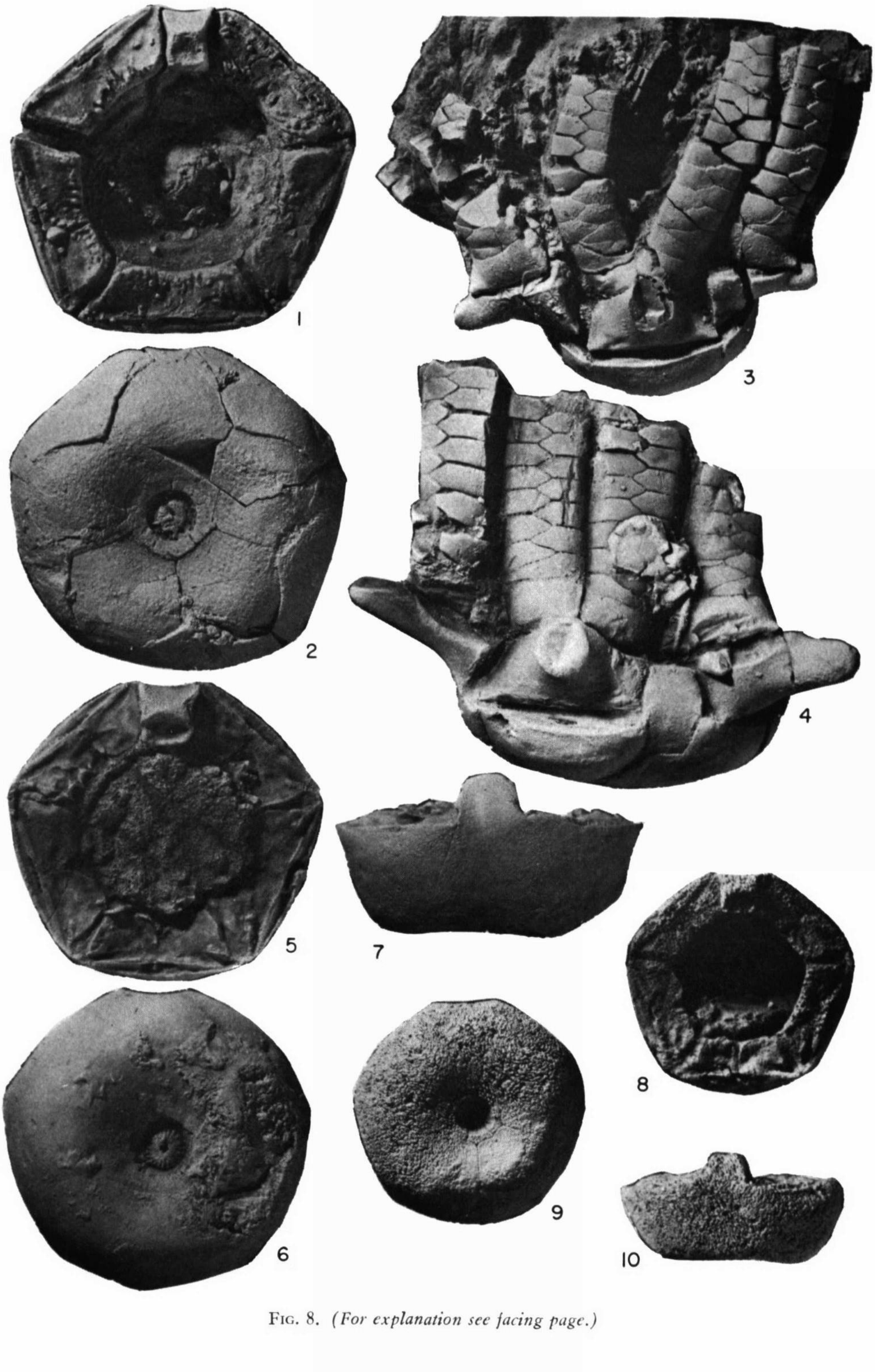

FIG. 8. *(For explanation see facing page.)*

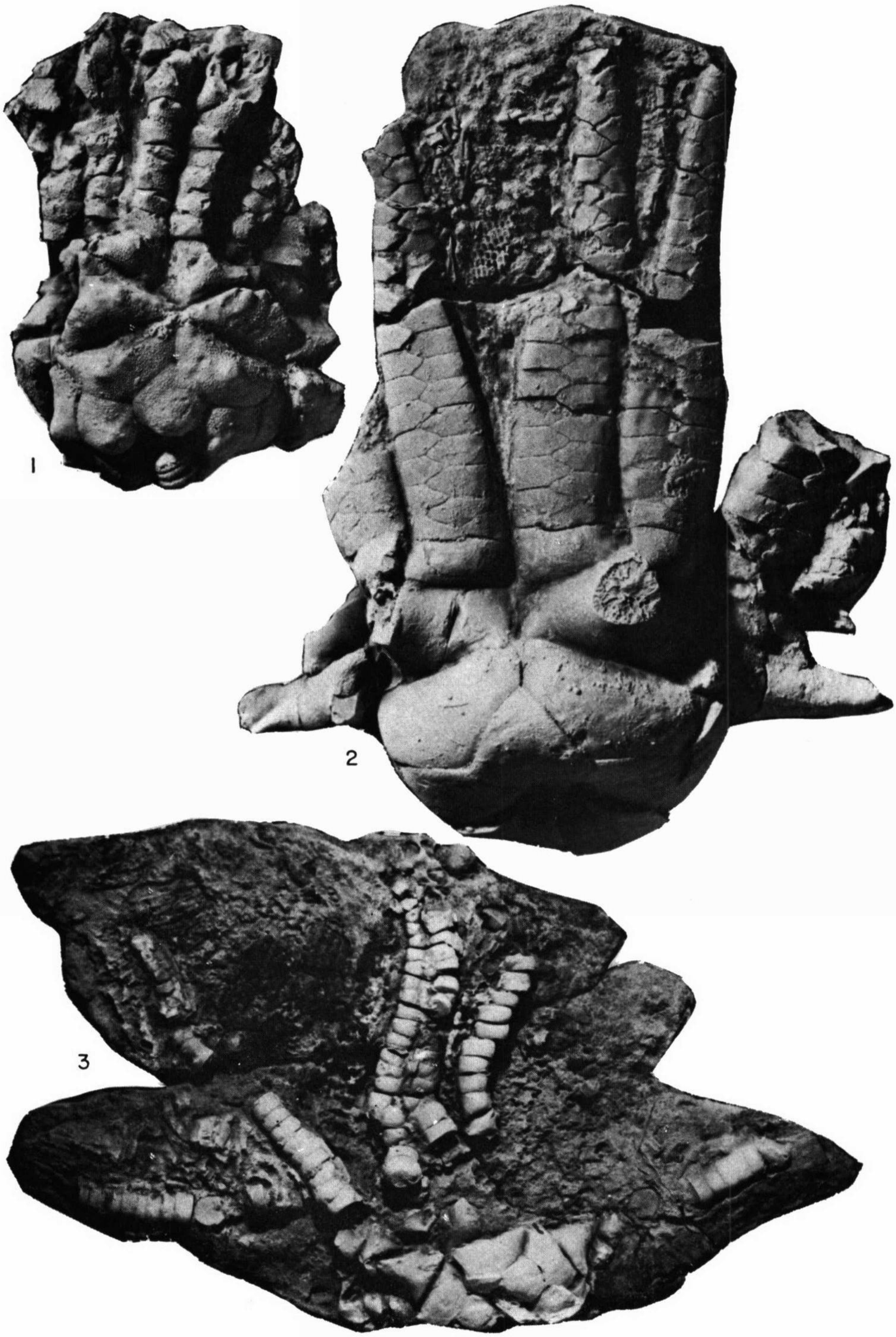

FIG. 9. *Triceracrinus topekensis* Moore *(1)*; *Paradelocrinus thurmanensis* Pabian & Strimple, n. sp. *(2)*; *Scytalocrinus fremontensis* Pabian & Strimple, n. sp. *(3)*.——*1. T. topekensis* Moore, anterior view of hypotype, UNSM 10155, ×3.——*2. P. thurmanensis* Pabian & Strimple, n. sp., ?anterior view of holotype, UNSM 10152, ×3.——*3. S. fremontensis* Pabian & Strimple, n. sp., left-posterior view of holotype, ×1.5.

tips rise about half the height of the cup. The radials are epaulette-shaped, and their proximal tips are slightly above the basal plane of the cup. They slope upward at about 75 degrees and curve inward near the summit of the cup. The primanal is rectangular and rests between the *C* and *D* radials and on the truncated *CD* basal below.

There are depressions at the junctions between adjacent radials and the subjacent basals and also at the junction between primanal, the *C* and *D* radials and the *CD* basal below.

The cup is weathered but the plates appear to have been smooth. Sutures between plates are very faint.

There is a sharp, outer marginal ridge and narrow, deep outer marginal furrow. The ligament pit is deep and the transverse ridge appears to have been denticulate. Lateral slopes rise to a sharp lateral ridge producing a V-shaped notch between adjacent articulating facets. The muscle areas slope inward to a broad, well-defined central pit which is connected to a deep, V-shaped, intramuscular notch by a short, deep, intramuscular furrow.

Remarks.—The specimen studied closely resembles both *Endelocrinus grafordensis* Moore & Plummer and *E. rotundus* Strimple; however, the similarity to the latter is more striking. It may be an intermediate in a lineage from *E. grafordensis* (Missourian) to *E. rotundus* (Wolfcampian).

Material Studied.—Hypotype UNSM 10153, was collected from an exposure adjacent to the type locality of the Coal Creek Limestone, SW ¼, SW ¼, NE ¼, sec. 14, T. 10 N., R. 14 E., Cass County, Nebraska.

Family GALATEACRINIDAE Knapp, 1969

Genus GALATEACRINUS Moore, 1940

GALATEACRINUS GOSSAMERI Pabian & Strimple, 1974

Figure 11, *4, 5*

Galateacrinus gossameri Pabian & Strimple, 1974, p. 286, pl. 6, fig. 16, 17.

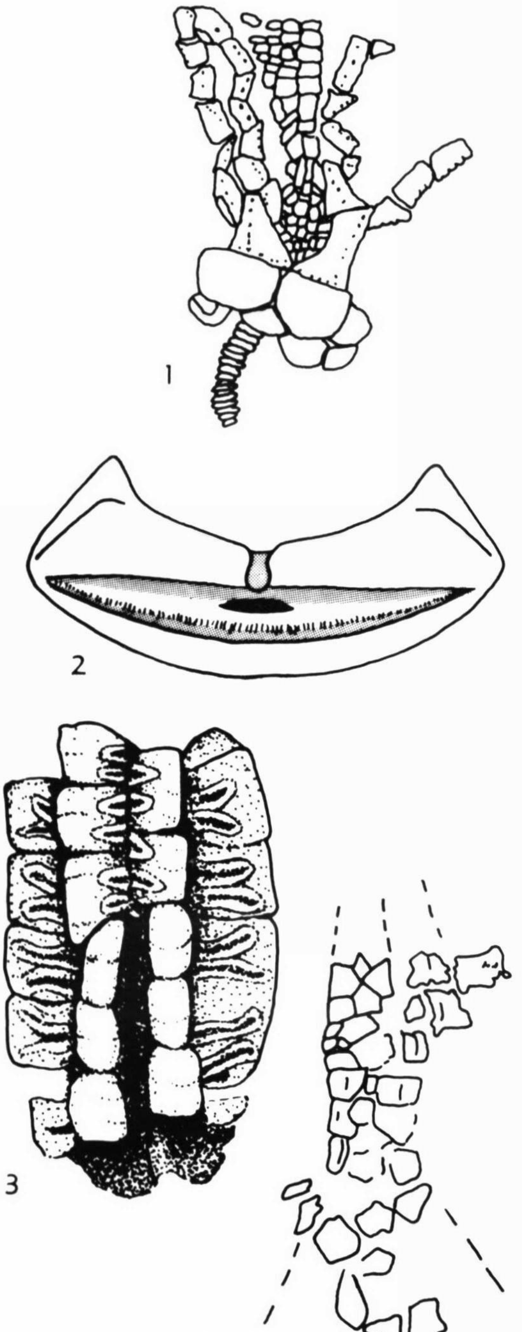

FIG. 10. *Glaukosocrinus forneyi* Pabian & Strimple, n. sp. *(1)*; *Scytalocrinus fremontensis* Pabian & Strimple, n. sp. *(2)*; *Triceracrinus topekensis* Moore *(3)*; *Paradelocrinus thurmanensis* Pabian & Strimple, n. sp. *(4)*.——*1*. *G. forneyi* Pabian & Strimple, n. sp., left posterior view, showing nature of lower arms and anal tube, holotype, UNSM 10168, ×3.——*2*. *S. fremontensis* Pabian & Strimple, n. sp., line drawing of ventral view of radial articular facet, from holotype, UNSM 10164, ×5.——*3*. *T. topekensis* Moore, line drawing of anal tube, from hypotype, UNSM 10155, ×3.——*4*. *P. thurmanensis* Pabian & Strimple, n. sp., line drawing of anal tube, from holotype, UNSM 10152, ×3.

Description.—*Galateacrinus gossameri* is represented by a single, damaged crown. The cup is a low, basally impressed disc. The five infrabasals are confined to a shallow concavity. There are five unequal, bulbous basals, the *AB, DE* and *EA* basals being pentagonal and the *BC* and *CD* basals being modified to a hexagon to accommodate the large primanal (radianal). The five radials are nearly flat-lying. The three plates in the anal series are in normal arrangement; the primanal is nearly a regular pentagon whereas the secundanal (anal *X*) is an irregular pentagon followed by a small, square, tertanal (right tube) plate.

The arm-articulating facets are subhorizontal. The outer marginal ridge is a broad, poorly defined structure. The outer marginal furrow is narrow and there is a transverse ridge with numerous, coarse denticles. The ligament pit appears broad, deep, and wide.

The nature of the midsection of the arms is indeterminate, but their distal ends appear to branch.

There are crossed ridges on the basal plates; these connect to diagonal ridges on the radial plates. There are a number of irregularly arranged nodes and tubercles on the radial plates and brachials. There is also a long, medially located ridge on each of the primibrachials.

Remarks.—The specimen under study is somewhat more ornate than the holotype; however, it is a much larger individual and the additional ornamentation is interpreted as being related to gerontic growth stages.

Material Studied.—Hypotype UNSM 10154.

Family SCYTALOCRINIDAE Moore & Laudon, 1943

Genus SCYTALOCRINUS Wachsmuth & Springer, 1880

Type Species.—*Scaphiocrinus robustus* Hall, 1861, p. 315.

Other Species Included.—*Scytalocrinus sansabensis* Moore & Plummer, 1938; *Hypselocrinus sansabensis* Moore & Laudon, 1944; *Scytalocrinus validus* Wachsmuth & Springer, 1897.

Diagnosis.—Dorsal cup cone-shaped. Five infrabasals nearly flat or sloping upward. Anal series in normal arrangement. Arms ten, uniserial, pinnulate.

SCYTALOCRINUS FREMONTENSIS Pabian & Strimple, new species

Figure 9, *3*; 10, *2*

Description.—*Scytalocrinus fremontensis* is based on a single, damaged crown. The five infrabasals form a nearly flat, pentagonal disk. The five basals are unequal, the *BC* and *CD* basals being modified for the reception of the primanal and secundanal plates. The proximal ends of the infrabasals are included in the broad, nearly flat base. The basals curve in a broad arc and their medial portions define the basal plane of the cup. The distal ends of the basals are visible in the side view of the cup. The primanal (radianal) is a large, barrel-shaped plate abutting the *BC* and *CD* basals below and being contained by the secundanal (anal *X*) and *C* radial above. Secundanal appears to be a six-sided plate contacting the *D* radial laterally and the primanal below. The five radials are tapered pentagons; their proximal ends slope upward, the slope steepening distally. Near the summit, the radials curve sharply inward for a short distance.

The radial articulating facets are well defined. The outer marginal ridge is fairly sharp and bounds a narrow outer ligament furrow. The outer ligament ridge is broad and denticulate and the transverse ridge is very sharp and well defined. There is an adsutural slope. The lateral ridges curve inward, forming a long, narrow muscle area that slopes gently inward to a small, distinct, circular central pit that divides the transverse ridge into nearly equal segments (Fig. 10,*2*). The central pit is connected to the wide semicircular intramuscular notch by a short, deep intramuscular furrow.

The isotomous primibrachials are long, subtriangular plates and the secundibrachials are

FIG. 11. *Paradelocrinus thurmanensis* Pabian & Strimple, n. sp. *(1-3)*; *Galateacrinus gossameri* Pabian & Strimple *(4,5)*; *Triceracrinus topekensis* Moore *(6,7)*; *Plaxocrinus gloukosensis* Strimple *(8,9)*.——*1-3*. *Paradelocrinus thurmanensis* Pabian & Strimple, n. sp., ventral, posterior, and dorsal views of paratype, UNSM 10418, ×2.——*4,5*. *G. gossameri* Pabian & Strimple, basal and ventral views of hypotype, UNSM 10154, ×2.——*6,7*. *T. topekensis* Moore, posterior and dorsal views of hypotype, UNSM 10155, ×3.——*8,9*. *Plaxocrinus gloukosensis* Strimple, posterior and dorsal views of hypotype, UNSM 10158, ×2.

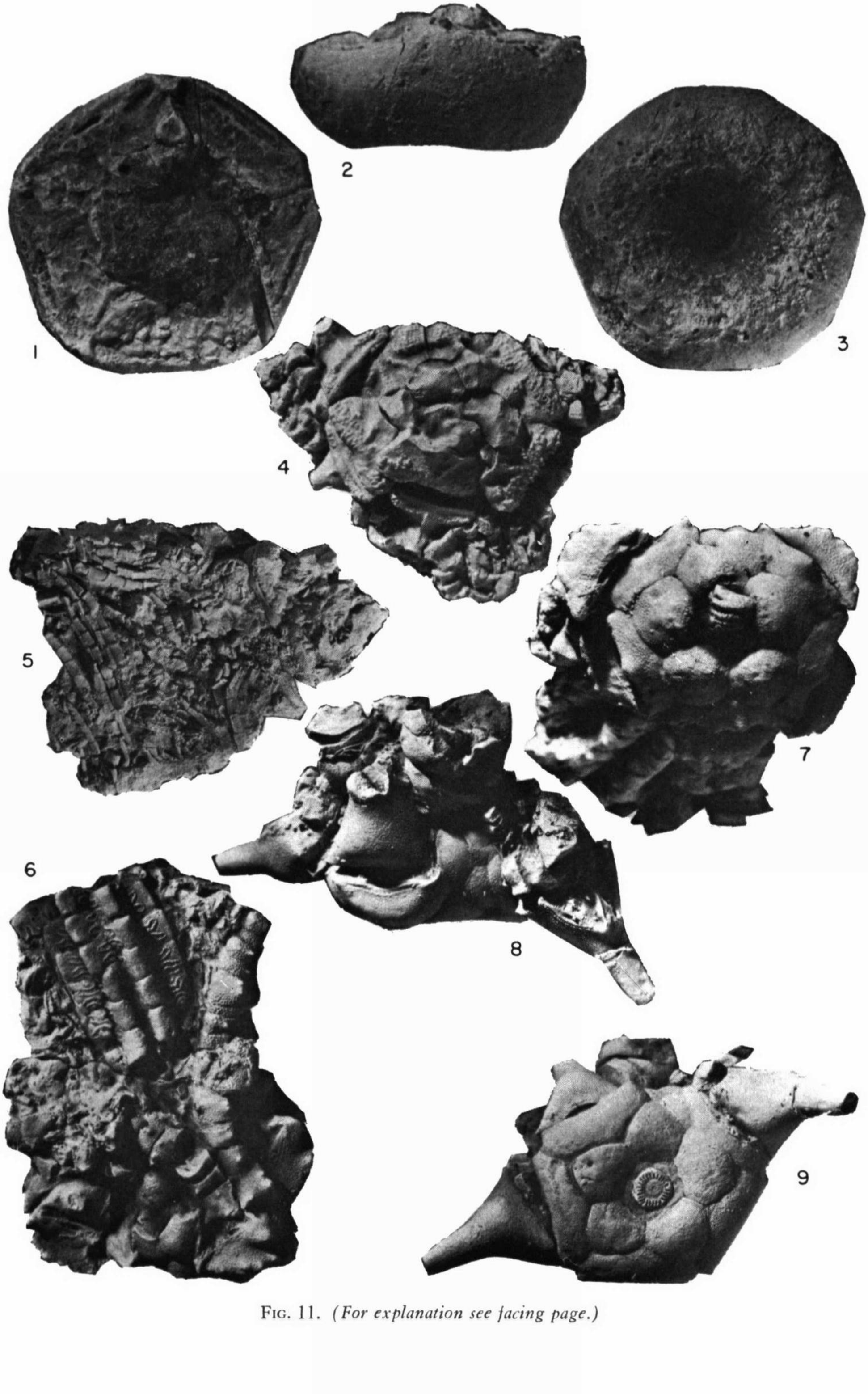

FIG. 11. *(For explanation see facing page.)*

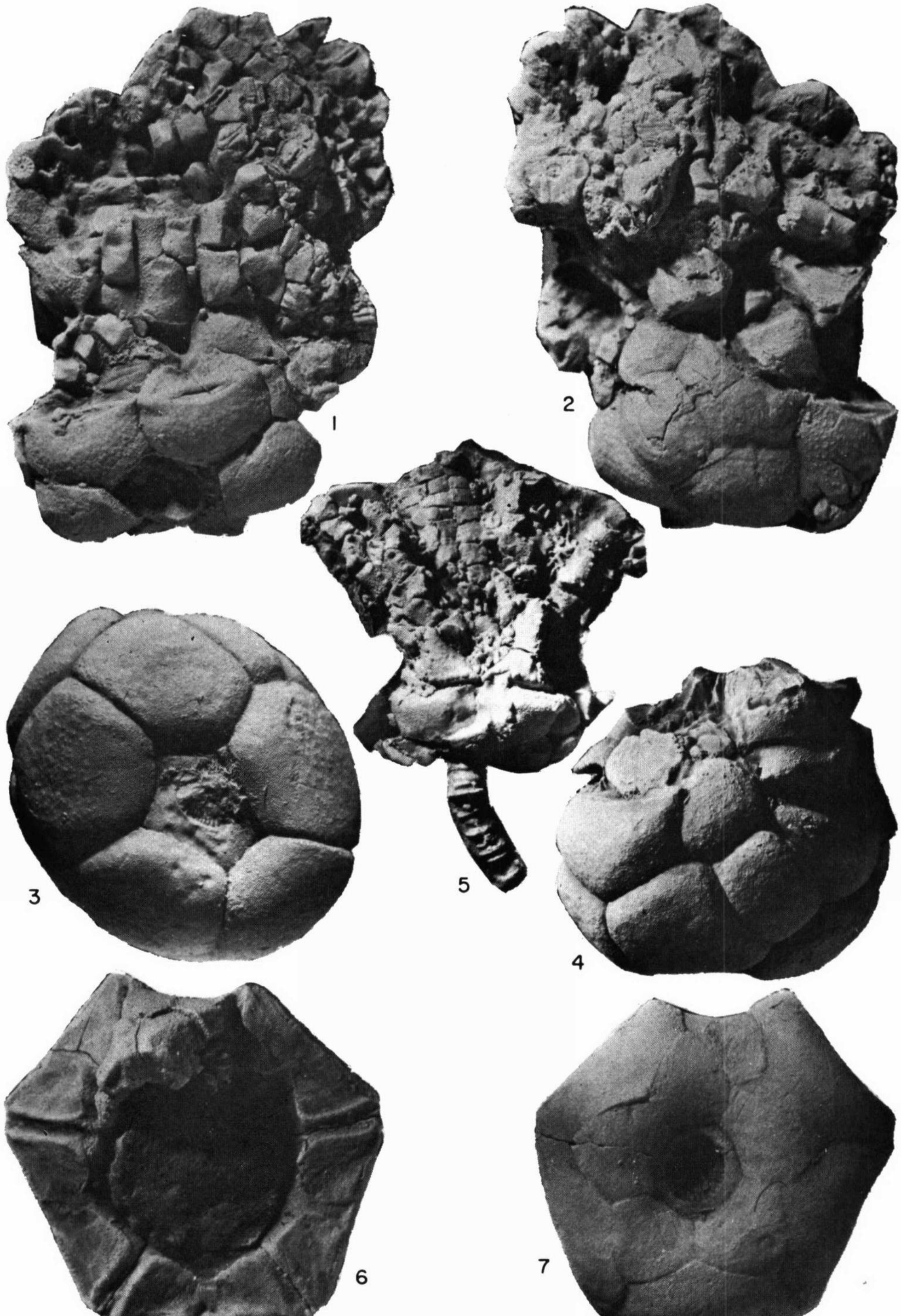

FIG. 12. *(For explanation see facing page.)*

small, equilateral triangles. The tertibrachials are round, disc-shaped plates that give rise to ten uniserial arms. The arms have about 25 segments, food grooves, and attachments for long, segmented pinnules.

Sutures between plates are distinct but not impressed. The interradial sutures appear to be denticulate.

Measurements.—See Appendix I.

Remarks.—*Scytalocrinus fremontensis* is named for Fremont County, Iowa. Several undescribed species of *Scytalocrinus* are known from both Missourian and Virgilian rocks of southwestern Iowa and southeastern Nebraska. The specimen studied most closely resembles *Scytalocrinus* sp. Pabian & Strimple, 1974, p. 289, text-fig. 2e, f, pl. 33, fig. 18; however, the latter specimen has some ornamentation, whereas the former is smooth.

Material Studied.—Holotype UNSM 10164.

Family PIRASOCRINIDAE Moore & Laudon, 1943

Genus TRICERACRINUS Bramlette, 1943

Type Species.—*Triceracrinus moorei* Bramlette, 1943, p. 550.

Other Species Included.—*Utharocrinus quinquacutus* Moore, 1939; *U. oreadensis* Moore, 1939; *U. topekensis* Moore, 1939; *U. fabulosus* Strimple, 1950; *U. spinosus* Strimple, 1950; *U. habitus* Strimple, 1950; *Perimestocrinus bulbosus* Strimple, 1962; *Lasanocrinus altamontensis* Strimple, 1950.

Diagnosis.—Basal and radial plates bulbous or spinose. No external ligament area present. Anal series in natural arrangement.

TRICERACRINUS TOPEKENSIS (Moore, 1938)

Figures 9, *1*; 10, *3*; 11, *6, 7*

Utharocrinus topekensis Moore, 1938, p. 244-245; text-fig. 19a, b; pl. VII, fig. 3a-c.

Triceracrinus topekensis Knapp, 1969, p. 380.

Emended Description.—(Emended to Moore, 1940, p. 244-245.) The primibrachials are short, spinose elements. Their lower portion forms a broad shelf that appears to abut against the distal area of the radials when the arms are in feeding position, and there are several nodes or tubercles just above this shelf. The primibrachial has a short, sharp spine at its termination. The first secundibrachial is triangular and has several nodes terminally. Six succeeding secundibrachials are uniserially arranged, trapezoidal plates. The first tertibrachial is a pentagonal, axillary element giving rise to an indeterminate number of quartibrachials. The arm segments are all pinnulate, and all bear fine, granular ornamentation.

The anal sac is stellate in outline. The plates are rectangular in outline and are arranged in a vertically imbricate pattern. The plates on the anal tube carry a linear ornamentation that connects each vertically arranged plate with both the upper and adjacent plate. (*See* Fig. 10, *3*.)

Remarks.—The geographic distribution of this species is extended from Jefferson County, Kansas, to Fremont County, Iowa.

Material Studied.—Hypotypes UNSM 10155-UNSM 10156.

Genus PLAXOCRINUS Moore & Plummer, 1938

PLAXOCRINUS GLOUKOSENSIS Strimple, 1952

Figures 11, *8, 9*; 12, *6, 7*

Plaxocrinus gloukosensis Strimple, 1952, p. 374-375, pl. 57, fig. 1-6; Pabian & Strimple, 1973, p. 61, pl. 5, fig. 8, 9.

Plaxocrinus cf. P. gloukosensis Strimple, 1971, p. 999, pl. 123, fig. 4.

Vertigocrinus gloukosensis Knapp, 1969, p. 378.

Remarks.—The range zone of *Plaxocrinus gloukosensis* is tentatively from the Merriam (Meadow) Limestone (Pabian and Strimple, 1974) to the Coal Creek Limestone. This species has also been reported from the Haskell (Cass) Limestone (Strimple, 1952) and Vinland Shale (Strimple, 1971). It therefore appears that this species is common to rocks ranging in age from the lower part of the Lansing Group (Missourian) to the upper part of the Shawnee Group (Virgilian). The species' geographic distribution is east-central Kansas, southeastern Nebraska, and southwestern Iowa.

Some of the specimens studied resemble *Plaxocrinus dornickensis* Strimple, 1949, because of the somewhat bulbous nature of the first primi-

FIG. 12. *Aglaocrinus cranei* Strimple *(1-4)*; *Glaukosocrinus forneyi* Pabian & Strimple, n. sp. *(5)*; *Plaxocrinus gloukosensis* Strimple *(6-7)*.——*1-4. A. cranei* Strimple; *1,2,* posterior and anterior views of an immature specimen, hypotype UNSM 10169, ×5; *3,4,* dorsal and posterior views of hypotype, UNSM 10165, ×2.——*5. G. forneyi* Pabian & Strimple, n. sp., left posterior view of holotype, UNSM 10168, ×3.——*6,7. P. gloukosensis* Strimple, ventral and dorsal views of hypotype, UNSM 10162, ×2.

brachials. These specimens appear to be in a lineage including both *P. mooresi* (Whitfield) and *P. dornickensis*.

Material Studied.—Hypotypes UNSM 10157, UNSM 10158-UNSM 10162.

Family DECADOCRINIDAE Bather, 1890

Genus GLAUKOSOCRINUS Strimple, 1951

Type species.—*Malaiocrinus parviusculus* Moore & Plummer, 1940, p. 100.

GLAUKOSOCRINUS FORNEYI Pabian & Strimple, new species

Figures 10, *1*; 12, *5*

Description.—*Glaukosocrinus forneyi* is based on a single, partial crown. The dorsal cup is a low bowl with a shallow but distinct basal concavity. The proximal portions of the five infrabasals are covered by a heteromorphic stem. The basals recurve near their proximal ends, and the basal plane of the cup is therefore situated near the proximal ends of the basals. The distal ends of the basals rise about 0.25 the height of the cup. The radials are epaulette-shaped and about twice as wide as long. The proximal tips of the radials are above the basal plane of the cup and the radials curve abruptly inward near the summit. There appear to be three anal plates: a rectangular primanal (radianal), a hexagonal secundanal (anal *X*), and an indeterminate-shaped, small tertanal (right tube) plate. Cup plates are ornamented with fine granules. Sutures between plates are distinct but not impressed.

The arm-articulating facets are nearly level and a fairly distinct outer marginal ridge and ligament pit can be discerned. There appear to be ten arms. The first primibrachials are long, slender axillary plates with rows of coarse tubercles along the base and along the length of the plate. Each primibrachial is followed by two secundibrachials directed obliquely outward and upward and each plate above is axillary, having a facet for a single, free armlet and another for an axillary plate similar to the one below. The arm plates are, thus, arranged in a zigzag fashion. Each arm plate has rows of tubercles at its base and along its length (Fig. 10, *1*).

The anal sac is slender and tall and composed of small plates arranged in several nonimbricate, vertical series. There are pores at some of the plate junctions.

Measurements.—See Appendix I.

Remarks.—This species is named in honor of the Forney family, whose members have most generously given the authors access to their property in order to collect specimens. *Glaukosocrinus forneyi* differs from *G. parvisculus* (Moore & Plummer) by having much coarser ornamentation, that of *G. parvisculus* being seen only with strong magnification.

Material Studied.—Holotype UNSM 10168.

Family CROMYOCRINIDAE Bather, 1890

Genus AGLAOCRINUS Strimple, 1961

AGLAOCRINUS CRANEI Strimple, 1971

Figure 12, *1-4*

Aglaocrinus cranei Strimple, 1971, p. 999, pl. 123, fig. 6, 7.

Remarks.—Two immature specimens studied do not have fully developed, biserially arranged arm segments characteristic of the species. One hypotype, UNSM 10170, shows a tendency toward developing biserial arms and several segments on the *C* ray are so arranged. A large, partial crown, UNSM 10171, has true, biserially arranged arms.

The range-zone of this species is tentatively from the Vinland Shale Member, Stranger Formation, Douglas Group through the Coal Creek Limestone, Topeka Formation, Shawnee Group, Virgilian Stage (Upper Pennsylvanian). The geographic distribution is east-central Kansas (Franklin County) and southwestern Iowa (Fremont County).

Material Studied.—Holotype SUI 34229, and hypotypes, UNSM 10165, UNSM 10167, UNSM 10169 and UNSM 10170.

REFERENCES

See composite list following Part 4.

PART 3

SOME CRINOIDS FROM THE CURZON AND ERVINE CREEK LIMESTONES (VIRGILIAN) OF CASS COUNTY, NEBRASKA

ABSTRACT

A sample of twenty-three dorsal cups and three partial crowns contains eleven crinoid species representing six families: Catacrinidae, Diphuicrinidae, Pirasocrinidae, Paradelocrinidae, Decadocrinidae, and Blothrocrinidae. The material was collected from the Ervine Creek and Curzon Limestones. The geographic distribution of *Delocrinus brownvillensis* is extended from northeastern Oklahoma to southeastern Nebraska and the tentative range-zone of this species is from the Ervine Creek Limestone, Deer Creek Formation, through the Brownville Limestone, Wood Siding Formation. *Paradelocrinus burdeni* Pabian & Strimple, new species, is described.

INTRODUCTION

The Curzon Limestone was originally named by Gallagher (1898) and redefined by Condra (1927, p. 52). The type locality is in the bluffs east of Curzon Station, Holt County, Missouri. Other exposures are near Iowa Point and Topeka, Kansas; Forest City, Missouri; and near Dubois, Union, and Nehawka, Nebraska. The crinoids described herein are from the latter two locations.

At Jones Point, east of Union, Nebraska, and 2½ miles north of Thurman, Iowa, the Curzon is discontinuous, ranging from 0 to 3 feet thick. The unit thickens southward, being about 6 feet at DuBois, Nebraska, and Forest City, Missouri. Near Iowa Point, Kansas, the Curzon is about 8 feet thick. Moore (1949, p. 163) indicated the Curzon in Kansas to be a very fossiliferous, persistent, prominent unit ranging in thickness from 5 to 12 feet.

The Ervine Creek Limestone was named by Condra (1927, p. 50) for Ervine Creek near Union, Cass County, Nebraska. Condra (1949, p. 22) indicated the Ervine Creek persisted from Adair County, Iowa, to Oklahoma, though he gave no name for the Oklahoma equivalent. Moore (1936, p. 188) redefined the Ervine Creek and made it divisible into two parts, the lower being the more persistent and prominent. Moore (1949, p. 160) indicated that the Pawhuska Limestone of Oklahoma is equivalent to the Ervine Creek. R. R. Burchett (personal communication) regards the Burroak Shale (Condra & Reed, 1937) and the Haynies Limestone (Condra, 1927) as being the basal members of the Ervine Creek. These beds contain a crinoid fauna considerably different in taxonomic content and associated fauna than that described here from the upper portion of the Ervine Creek. The former fauna will be the subject of a subsequent investigation.

The crinoids were collected from the Curzon Limestone at Jones Point, east of Union, Nebraska, in the SW ¼, NW ¼, sec. 21, T. 10 N., R. 14 E. (Location 1, Fig. 13), and from the Ervine Creek Limestone about 2.5 miles south of Nehawka, Nebraska, in the SW ¼, NE ¼, sec. 29, T. 10 N., R. 13 E., Cass County, Nebraska (Location 2, Fig. 13). Both exposures are in abandoned quarries. All specimens are reposited in the University of Nebraska State Museum (UNSM).

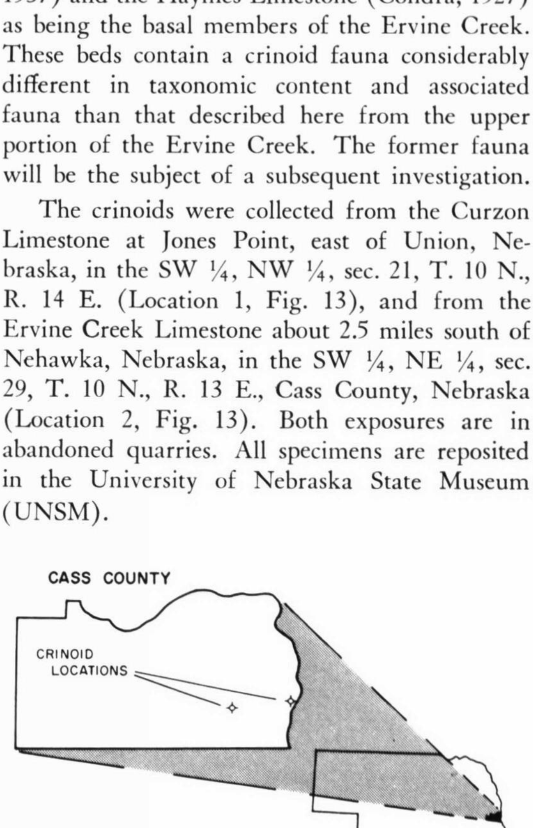

Fig. 13. Index map of Cass County, Nebraska, showing crinoid locations.

ACKNOWLEDGMENTS

All specimens described herein were collected by W. D. White, Omaha, Nebraska. Figure 13 was drawn by Barbara Force, and the manuscript was typed by Doris Peabody, both of the Nebraska Conservation and Survey Division, University of Nebraska.

SYSTEMATIC PALEONTOLOGY

Phylum ECHINODERMATA Laske, 1778

Subphylum PELMATOZOA Leuckart, 1848

Class CRINOIDEA Miller, 1821

Subclass INADUNATA Wachsmuth & Springer, 1885

Order CLADIDA Moore & Laudon, 1943

Superfamily ERISOCRINACEA Wachsmuth & Springer, 1886

Family CATACRINIDAE Knapp, 1969

Genus DELOCRINUS Miller & Gurley, 1890

DELOCRINUS BROWNVILLENSIS Strimple, 1949

Figure 14, *1-4*

Delocrinus brownvillensis Strimple, 1949, p. 22-23, pl. 4, fig. 1-4; 1962, p. 109-110; Pabian & Strimple, 1973, p. 22-23, fig. 1, 2, table 1.

Remarks.—The tentative range-zone of *Delocrinus brownvillensis* is now thought to be from the Curzon Limestone, Topeka Formation, Shawnee Group, Virgilian Stage, through the Brownville Limestone, Wood Siding Formation, Wabaunsee Group, Virgilian Stage (Upper Pennsylvanian). The geographic distribution of this species is Osage County, Oklahoma, Cass County, Nebraska, and Wabaunsee County, Kansas.

Material Studied.—Seven hypotypes UNSM 10375 through UNSM 10379, Ervine Creek Limestone, Location 2, and UNSM 10380 and UNSM 10381 collected from Curzon Limestone, Location 1.

DELOCRINUS HEMISPHERICUS (Shumard, 1858)

Figure 14, *5*

For synonymies, see p. 21.

Remarks.—*Delocrinus hemisphericus* is separable from *D. brownvillensis* on the basis of shorter, less protruding primibrachials, a shallower basal concavity, and a somewhat more ovate profile of the dorsal cups of the latter. The present study indicates these two species to be quite closely related, *D. brownvillensis* possibly being directly descended from *D. hemisphericus.*

The sample of *Delocrinus hemisphericus* under investigation shows there is a strong tendency toward forms evolving broad, shallow basal concavities from deep, narrow concavities. Such a tendency is exhibited by *D. hemisphericus* from the younger Coal Creek Limestone and the much older Stull Shale. (*See* Part 2, p. 21.)

Material Studied.—Four hypotypes UNSM 10382 through UNSM 10385, collected from Ervine Creek Limestone, Location 2.

Genus ENDELOCRINUS Moore & Plummer, 1940

Type Species.—*Eupachycrinus fayettensis* Worthen, 1873, p. 565.

ENDELOCRINUS sp. cf. E. ALLEGHENIENSIS (Burke, 1932)

See Pabian & Strimple, 1974, p. 279, for synonymy to date.

Remarks.—The specimen under study here appears to have two tumor-like growths, one between the *A* and *E* radials and the other between *B* and *C* radials. Though this specimen is somewhat smaller than the holotype of *Endelocrinus allegheniensis* (see Burke, 1932) and the hypotype described by Pabian & Strimple (1974, p. 279-280), it is comparable to this species because of the extreme bulbosity of the radial plates.

Material Studied.—Hypotype UNSM 10397, Location 2.

Family DIPHUICRINIDAE Strimple & Knapp, 1966

Genus GRAFFHAMICRINUS Strimple, 1961

GRAFFHAMICRINUS STULLENSIS (Strimple, 1947)

Figure 15, *1-3*

Delocrinus stullensis Strimple, 1947, p. 5-6, pl. 2, fig. 4-6.
Graffhamicrinus stullensis Pabian & Strimple, 1973, p. 33-34, pl. 2, fig. 4-5, table 15.

Remarks.—The specimen described is a disfigured individual comparable to UNSM 7990 (see Pabian & Strimple, 1974, pl. 33, fig. 4, 5), the *D* radial of the cup being very low, the *C* radial higher, and the *B* radial the highest. Another hypotype, UNSM 10402, collected from the same locality as UNSM 7990 (Soldier Creek Limestone, Wabaunsee Group, Virgilian Stage, near Unadilla, Nebraska, loc. 19, Append. I, of

Pabian & Strimple, 1974, p. 290) is disfigured in the same manner. The holotype, collected from the Stull Shale, near Melvern, Kansas, however, is not so disfigured. In all respects, except the disfiguring, however, the dorsal cups are identical to the holotype. This suggests that at least some lineages of *Graffhamicrinus stullensis* developed a tendency toward elongation of the *A* and *B* radials. Current data is insufficient to determine whether this tendency represents a lineage of "freaks" that survived or whether it indicates some form of ecological adaptation.

Material Studied.—Hypotypes UNSM 7990, UNSM 10401, Soldier Creek Limestone, Wabaunsee Group, Virgilian Stage (Upper Pennsylvanian), location 19 of Pabian and Strimple, 1974, p. 61. Hypotype, UNSM 10402, Curzon Limestone, Location 1.

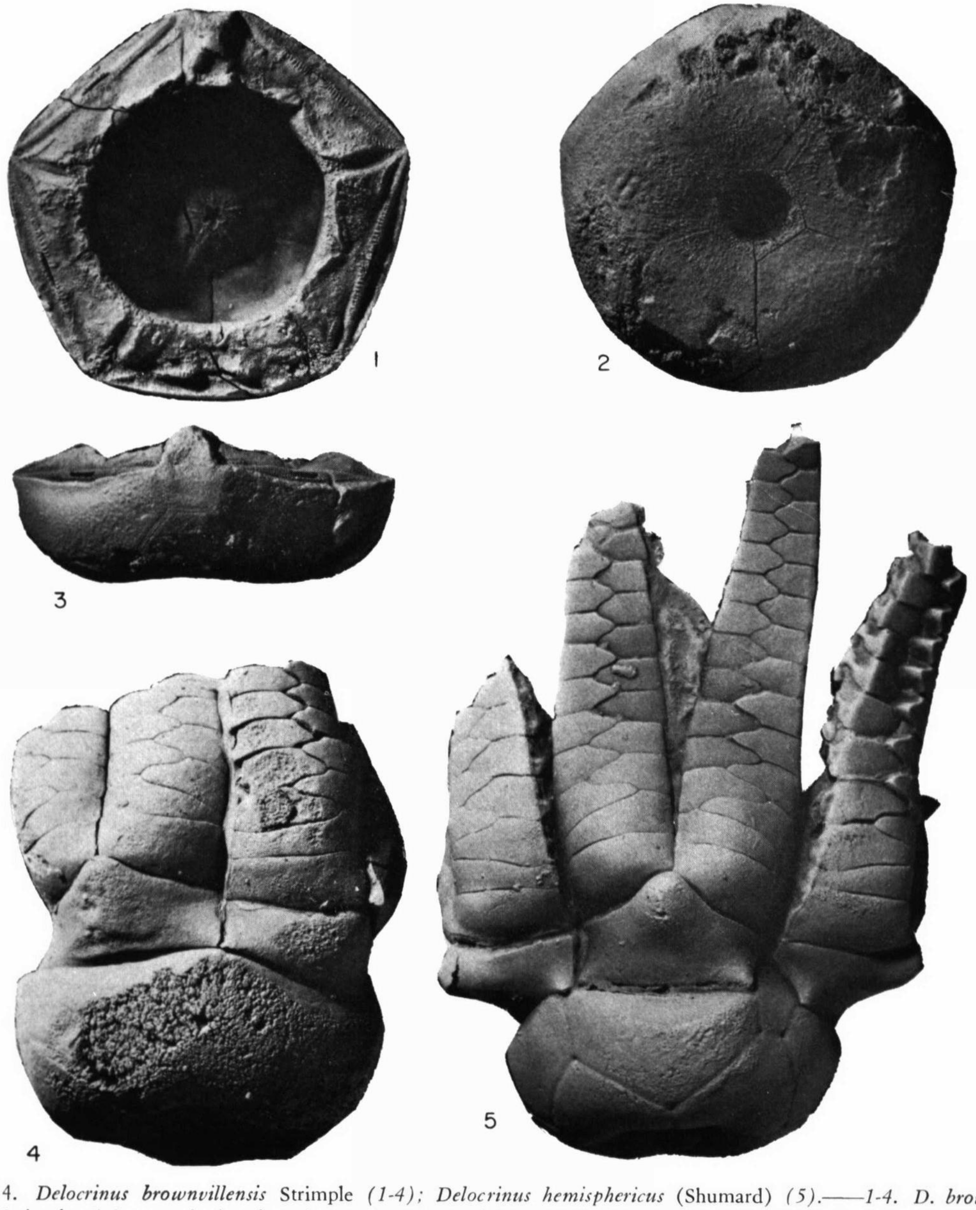

FIG. 14. *Delocrinus brownvillensis* Strimple *(1-4)*; *Delocrinus hemisphericus* (Shumard) *(5)*.——*1-4*. *D. brownvillensis* Strimple; *1-3*, ventral, dorsal, and posterior views of hypotype, UNSM 10376, ×2; *4*, anterior view of hypotype, UNSM 10375, ×2.——*5*. *D. hemisphericus* (Shumard), left posterior view of hypotype, UNSM 10382, ×2.

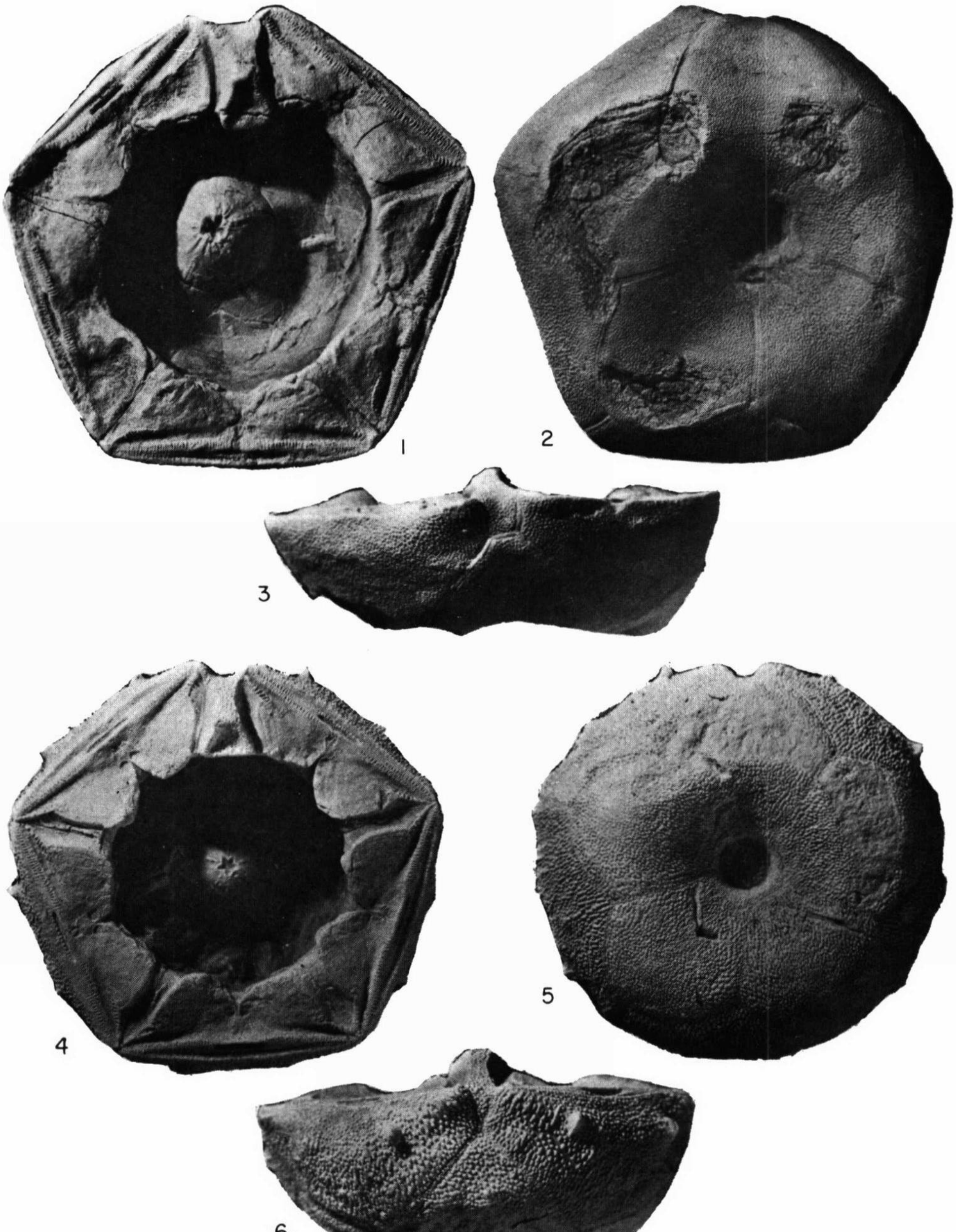

FIG. 15.——*1-3. Graffhamicrinus stullensis* (Strimple), ventral, dorsal, and posterior views of hypotype, UNSM 10402, ×2.——*4-6. G. magnificus* (Strimple), ventral, dorsal, and posterior views of hypotype, UNSM 10387, ×2.

GRAFFHAMICRINUS MAGNIFICUS (Strimple, 1947)

Figure 15, *4, 6*; 16, *1*

Delocrinus magnificus Strimple, 1947, p. 3-5, pl. 1, fig. 1-4; Pabian & Strimple, 1973, p. 31, pl. 2, fig. 1-3.

Remarks.—Hypotype UNSM 10386 shows no tendency toward eliminating the primanal (anal X), whereas this tendency is demonstrated by hypotype UNSM 10387. Hypotype UNSM 7975 (*see* Pabian & Strimple, 1974, p. 270) retains the primanal as only a rudimentary element ("Extreme type," Strimple, 1949, p. 123-124), whereas hypotype UNSM 10387 (this paper) retains the primanal in the "Advanced type" arrangement where the anal plate is still in contact with the *C* and *D* radials but has just lost contact with the *CD* basal. Hypotypes UNSM 10389 and UNSM 10390 retain the primanal in the "normal" arrangement, contacting the *C* and *D* radials and *CD* basal.

This species exhibits a lineage in which the basal concavity evolves from deep and narrow to shallow and wide, a tendency common to both *Graffhamicrinus,* a diphuicrinid and *Delocrinus,* a catacrinid. *Graffhamicrinus* forms with a very deep basal concavity have been assigned to *G. profundus* Strimple (1971, p. 998-999). The catacrinid, *Subarrectocrinus perexcavatus* (Moore & Plummer) has a basal concavity similar to that of *G. profundus.* The samples in this study indicate similar evolutionary tendencies in two not closely related families.

Material Studied.—Four hypotypes UNSM 10386 and UNSM 10387, UNSM 10388 and UNSM 10389, Ervine Creek Limestone, Location 2.

GRAFFHAMICRINUS GRAPHICUS
(Moore & Plummer, 1940)
Figure 16, *2-4*

Delocrinus graphicus Moore & Plummer, 1940, p. 273-274, pl. 12, fig. 4-11; Shimer & Shrock, 1944, p. 173, pl. 65, fig. 16.

Graffhamicrinus graphicus Pabian & Strimple, 1973, p. 271-272, pl. 33, fig. 1-3.

Remarks.—*Graffhamicrinus graphicus* has less ornamentation than *G. magnificus,* and that of the latter is more crude and random in distribution, and consists of nodes and tubercles. *G. magnificus* has regularly distributed nodes or tuber-

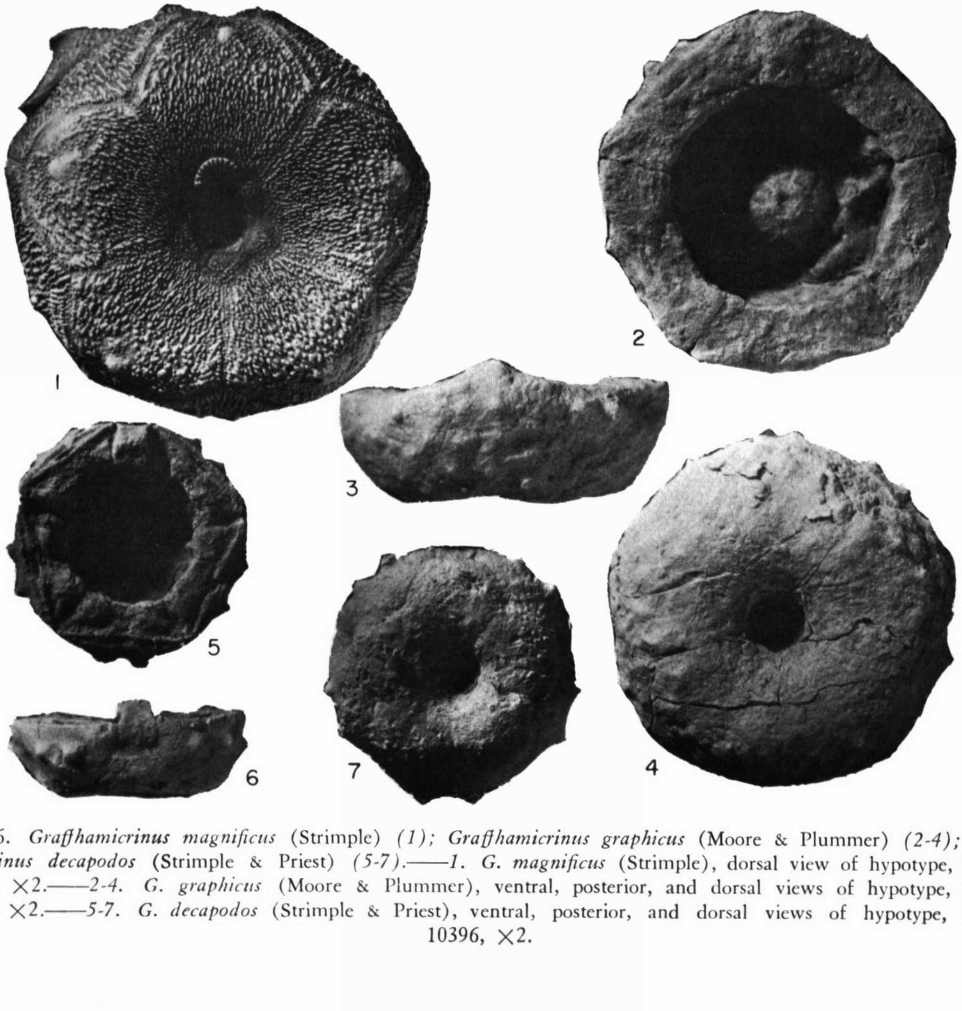

FIG. 16. *Graffhamicrinus magnificus* (Strimple) *(1)*; *Graffhamicrinus graphicus* (Moore & Plummer) *(2-4)*; *Graffhamicrinus decapodos* (Strimple & Priest) *(5-7)*.——*1*. *G. magnificus* (Strimple), dorsal view of hypotype, UNSM 10386, ×2.——*2-4*. *G. graphicus* (Moore & Plummer), ventral, posterior, and dorsal views of hypotype, UNSM 10391, ×2.——*5-7*. *G. decapodos* (Strimple & Priest), ventral, posterior, and dorsal views of hypotype, UNSM 10396, ×2.

cles as well as numerous, sharp ridges that appear to be oriented in a parallel fashion.

Material Studied.—Hypotypes UNSM 10391-UNSM 10393, Ervine Creek Limestone, Location 2; UNSM 10394, Curzon Limestone, Location 1.

GRAFFHAMICRINUS DECAPODOS (Strimple & Priest, 1969)

Figure 16, *5-7*

Tholiacrinus decapodos Strimple & Priest, 1969, p. 23, fig. 9,*1-4*.

Remarks.—The tentative range-zone of *G. decapodos* is from the Stull Shale Member, Kanwaka Formation, through the Curzon Limestone Member, Topeka Formation, both of the Shawnee Group, Virgilian Stage (Upper Pennsylvanian).

The specimen has a pair of large nodes on each radial plate; the fine granules surrounding these nodes, however, are not nearly as coarse as those on the figured holotype.

Tholiacrinus Strimple, 1962, has been synonymized with *Graffhamicrinus* by Moore & Strimple, 1973, p. 22.

Material Studied.—Hypotype UNSM 10396, Ervine Creek Limestone, Location 2.

Family DECADOCRINIDAE Strimple & Moore, 1971

Genus GLAUKOSOCRINUS Strimple, 1951

Type Species.—*Malaiocrinus parviusculus* Moore & Plummer, 1940, p. 100.

GLAUKOSOCRINUS sp. cf. G. FORNEYI Pabian & Strimple, 1974

Glaukosocrinus forneyi Pabian & Strimple, 1974, herein, Part 2, p. 30, fig. 10,*1*;12,*5*.

Remarks.—The specimen examined has somewhat finer granules on cup plates than does the holotype of *Glaukosocrinus forneyi*. Since the arms are not present, no comparison of these to *G. forneyi* can be made. The arm-articulating facets of this specimen are nearly level but not well preserved. A distinct outer marginal ridge and a deep ligament pit are easily discernible.

Material Studied.—Hypotype UNSM 10395, Ervine Creek Limestone, Location 2.

Family PARADELOCRINIDAE Knapp, 1969

Genus PARADELOCRINUS Moore & Plummer, 1938

Type Species.—*Paradelocrinus aequabilis* Moore & Plummer, 1938, p. 294.

PARADELOCRINUS BURDENI Pabian & Strimple, new species

Figure 17, *1, 2*

Description.—*Paradelocrinus burdeni* is based on a single dorsal cup with all five first primibrachials attached. The basal concavity is broad and funnel-shaped. The infrabasals are covered by the proximal columnals. The proximal portions of the five basals slope downward about 45 degrees; the basals recurve just short of their midlengths, forming the basal plane of the cup; the distal parts of the basals slope upward at about 45 degrees, terminating at about half the height of the cup except for a single basal that rises about 0.75 the height of the cup and that is thought to be the *CD* basal. The five radials are epaulette-shaped; their proximal points are just slightly above the basal plane of the cup. The radials rise at a progressively steeper slope and curve inward near their summit.

The five primibrachials are somewhat protruded, subpentagonal axillary elements that are faceted for the reception of secundibrachials. The paired facets of the primibrachials each have a single groove that leads to a larger groove. Each of the ten facets has an outer marginal ridge, outer ligament furrow, ligament pit, transverse ridge, and denticles.

The stem is about 5 mm in diameter near the cup and is composed of alternately larger and smaller, crenulated columnals with a pentalobate lumen.

Measurements.—See Appendix I.

Remarks.—*Paradelocrinus burdeni,* named for B. C., Paul, and James Burden, differs from *P. thurmanensis* by having a somewhat higher dorsal cup and shorter, less spinose primibrachials. *P. burdeni* has a much deeper basal concavity and differently configured plates than *P. brachiatus, P. subplanus,* or *P. protensus.*

Material Studied.—Holotype UNSM 10398, Curzon Limestone, Location 1.

Superfamily PIRASOCRINACEA Moore & Laudon, 1943

Family PIRASOCRINIDAE Moore & Laudon, 1943

Genus PLAXOCRINUS Moore & Plummer, 1938

Type Species.—*Hydreionocrinus crassidiscus* Miller & Gurley, 1894, p. 43.

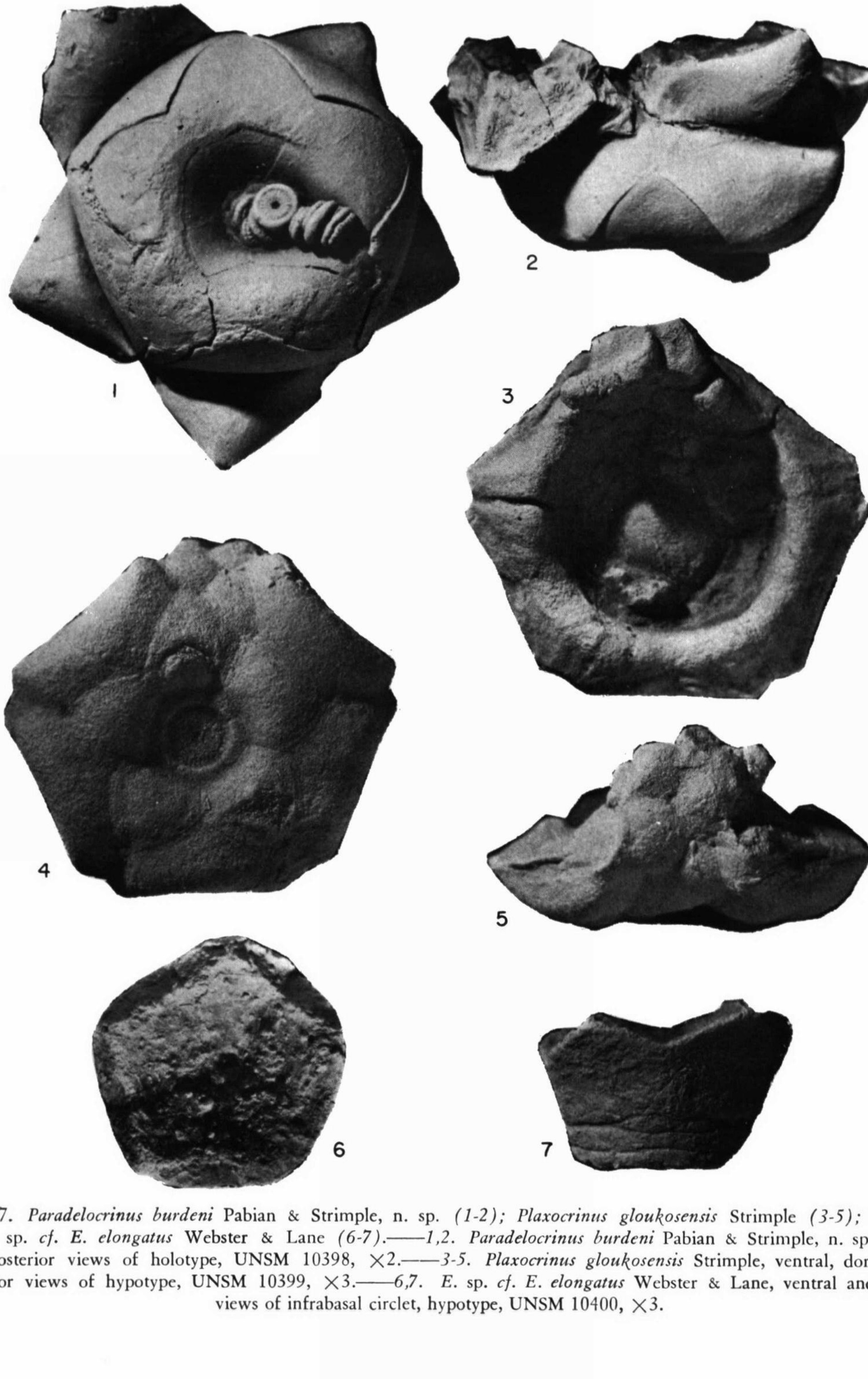

FIG. 17. *Paradelocrinus burdeni* Pabian & Strimple, n. sp. *(1-2)*; *Plaxocrinus gloukosensis* Strimple *(3-5)*; *Elibatocrinus* sp. *cf. E. elongatus* Webster & Lane *(6-7)*.——*1,2. Paradelocrinus burdeni* Pabian & Strimple, n. sp., dorsal and posterior views of holotype, UNSM 10398, ×2.——*3-5. Plaxocrinus gloukosensis* Strimple, ventral, dorsal, and posterior views of hypotype, UNSM 10399, ×3.——*6,7. E.* sp. *cf. E. elongatus* Webster & Lane, ventral and lateral views of infrabasal circlet, hypotype, UNSM 10400, ×3.

PLAXOCRINUS GLOUKOSENSIS Strimple, 1951
Figure 17, *3-5*

Plaxocrinus gloukosensis Strimple, 1951, p. 374, pl. 57, fig. 1-6.

Remarks.—The *CD* basal is replaced by two plates, a small shield-shaped plate, as the other basals, followed by an arrowhead-shaped plate (Fig. 17,*4*).

The tentative range-zone of *Plaxocrinus gloukosensis* extends from the Merriam (Meadow Limestone, Lansing Group, Missourian Stage, through the Curzon Limestone, Topeka Formation, Shawnee Group, Virgilian Stage (Upper Pennsylvanian).

Material Studied.—Hypotype UNSM 10399, Location 1.

Superfamily SCYTALOCRINACEA Moore & Laudon, 1943

Family BLOTHROCRINIDAE Moore & Laudon, 1943

Genus ELIBATOCRINUS Moore, 1940

ELIBATOCRINUS sp. cf. E. ELONGATUS Webster & Lane, 1967
Figure 17, *6, 7*

cf. *Elibatocrinus* sp. Lane & Webster, 1966, p. 30, pl. 10, fig. 7.

cf. *Elibatocrinus elongatus* Webster & Lane, 1967, p. 16-17, pl. 5, fig. 1, 2.

Remarks.—The specimen under study is an infrabasal circlet with three plates, two of which consist of fused, paired plates. Several columnals are attached to the infrabasals; the most proximal of these are incompletely formed (Fig. 17,*6*,*7*), thus showing the method of columnal development.

This specimen appears to be more closely allied to the holotype of *Elibatocrinus elongatus* Webster & Lane than the specimen figured and compared to *E. elongatus* by Pabian & Strimple (1974, p. 308). The infrabasals of this specimen flare out immediately from the base of the cup, whereas those on the Oklahoma specimen first assume a vertical attitude and then flare out somewhat above the base of the cup.

Material Studied.—Hypotype UNSM 10400, Ervine Creek Limestone, Location 2.

REFERENCES

See composite list following Part 4.

PART 4

BIOMETRICAL STUDY OF THE MORPHOLOGY AND DEVELOPMENT OF A NEW SPECIES OF TERPNOCRINUS STRIMPLE & MOORE, PENNSYLVANIAN, NEBRASKA

ABSTRACT

Thirty cups of *Terpnocrinus ellipticus* Pabian & Strimple, new species, have been collected from the Kiewitz Shale zone, Stoner Limestone Member, Stanton Formation, Lansing Group, Missourian Stage, Upper Pennsylvanian, exposed in four quarries along the Lower Platte River Valley in Cass and Sarpy Counties, Nebraska (Fig. 18).

Scatter diagrams of nine pairs of measurements of cups indicate rectilinear point distribution. Changes in morphology during growth include a change in cross section of the dorsal cup from a medium-high cone to a medium-high, truncate bowl. This was brought about by material being added between adjacent radial plates at a much greater rate than it was added between adjacent basal plates.

The new species of *Terpnocrinus* has also been collected from the upper part of the Stanton Limestone, Lansing Group, Missourian Stage (Upper Pennsylvanian), in Wilson County, Kansas; the Wann Formation, Ochelata Group, Missourian Stage, exposed at

The Mound, at the west edge of Bartlesville, Osage County, Oklahoma; and from the Graford Formation, Canyon Group, Missourian Stage, Lake Bridgeport, Wise County, Texas.

FIG. 18. Index map of the North American Mid-Continent region showing locations from which crinoids described in the paper were collected. For legal descriptions and stratigraphic data, see Systematic Paleontology, Material Studied (p. 49).

INTRODUCTION

The genus *Terpnocrinus* Strimple & Moore was based on a single, well-preserved crown described as *Terpnocrinus ocoyaensis* Strimple & Moore, 1971, from the La Salle Limestone Member, Bond Formation, Missourian Stage (Upper Pennsylvanian), of Livingston County, Illinois. A juvenile partial crown and 29 dorsal cups of *Terpnocrinus* have been collected from the Kiewitz Shale zone, Stoner Limestone Member, Stanton Formation, Missourian Stage (Upper Pennsylvanian), from several closely situated outcrops in the Lower Platte River Valley in Cass and Sarpy Counties, of eastern Nebraska. These will be relegated to *Terpnocrinus ellipticus* Pabian & Strimple, new species. In addition to the material from Nebraska, several conspecific specimens have been collected from the Stanton Formation exposed west of Altoona, Kansas; from the Wann Formation exposed near Bartlesville, Oklahoma; and from the Wolf Mountain Shale, Graford Formation (all Upper Pennsylvanian) near Lake Bridgeport, Texas.

The Kiewitz Shale zone of the Stoner Limestone was named by Condra (1927, p. 42, 55) for exposures in the Kiewit Quarry located in the Platte Valley Bluffs west of Meadow Station, Sarpy County, Nebraska. This zone consists of about 3.0 feet of gray, very fossiliferous, calcareous shale. Lindsay (1971) indicated that the Kiewitz Shale contained a *Neochonetes* (brachiopod) community.

The material studied is now reposited in the geological collections of the University of Iowa (SUI), the Illinois Geological Survey (IGS), and in the University of Nebraska State Museum (UNSM).

ACKNOWLEDGMENTS

Most of the 30 cups of the Nebraska species were collected from four closely situated exposures of Kiewitz Shale, Upper Missourian, by W. D. White, a well-known amateur collector in Nebraska. The Texas specimen was collected by Allen Graffham. One cup from the Stanton Formation of Nebraska was collected by Bill Ruschlau. Additional specimens have been collected by the authors from the Stanton Limestone near Altoona, Kansas, and the Wann Shale near Bartlesville, Oklahoma. The manuscript was typed by Doris Peabody and Nicki Smith and drafting of figures was done by Perry Poyner, Tom Koch, and Barbara Force, all of the Nebraska Conservation and Survey Division, University of Nebraska. Typing and drafting was supported by the Conservation and Survey Division of the University of Nebraska.

MORPHOLOGY OF TERPNOCRINUS

DORSAL CUP

The cup of *Terpnocrinus* is typically a medium-high globose-shaped body with the anal plates in an advanced arrangement, Extreme Type (1) designated by Strimple (1960) where the primanal (radianal) (Moore & Strimple, 1973, p. 13) lies diagonally across the distal facet of the *CD* basal and is followed above by the secundanal (anal *X*) and tertanal (right tube) plates, which form a common distal plane and develop articulating facets with outer ligament furrows, transverse ridges, and muscle areas. The midportion of the infrabasal circlet is depressed and bounded by means of short sloping walls, with the columnar cicatrix either horizontal or slightly downflared. Beyond the impression, the infrabasals are either subhorizontal or slightly downflared.

The cups of the Nebraska specimens of *Terpnocrinus* are moderately tall and bowl-shaped. There are decided depressions at the corners of the cup plates, and the sutures are moderately impressed.

In the closely related *Haeretocrinus* Moore & Plummer, 1940, the dorsal cup is tall and cone-shaped, with the cup rising evenly from the columnar scar. In most species of *Haeretocrinus,* the anal plates are in Extreme Type (1) arrangement. *Texacrinus* Moore & Plummer, 1940, has a bowl-shaped dorsal cup with a basal invagination and anal plates in Extreme Type (1) arrangement.

ARMS

The arms of *Terpnocrinus* are uniserial, with rather short, well-rounded brachials, the first bifurcation taking place on primibrachial *1* in all rays. Subsequent brachials are pinnulate, bearing a single pinnule on each alternate side. A second branching takes place with secundibrachial *5-8* (Fig. 19,*1*,*2*), but even in the holotype of the type species *Terpnocrinus ocoyaensis,* only a few subsequent brachials are preserved. A hypotype of *T. ocoyaensis,* UNSM 10032, branches at secundibrachial *5* on the *A* ray and shows no indication of branching at secundibrachial *7* in the *E* ray (Fig. 19,*2*), so this avenue of branching may vary from ray to ray or even from specimen to specimen. *Terpnocrinus ellipticus* Pabian & Strimple, new species, shows no evidence of branching at secundibrachial *5* on the *D* ray (Fig. 19,*3*).

Haeretocrinus has arms similar to those of *Terpnocrinus.* In the type species, *Haeretocrinus missouriensis* Moore & Plummer (1940, p. 110-113) the second branching is on secundibrachial *5,* with at least six subsequent tertibrachials following in the *B* ray. *Haeretocrinus turbinatus* Strimple (1952, p. 245-248) from the Wann Formation of Oklahoma, which also has an Extreme Type (1) anal plate arrangement, typically bifurcates with secundibrachial *4-5* and is known to have two subsequent branchings in the inner half-rays only with tertibrachial *6* and quatrobrach *5* (Fig. 19,*4*). *Haeretocrinus wagneri* Strimple & Moore (1971, p. 23) from the La Salle Limestone of Illinois, which has a primitive type anal plate arrangement, has more primitive arm branching, i.e., a second bifurcation with secundibrachial *6-8,* which may delay to secundibrachial *9.* A third bifurcation with tertibrachial *10* is known in inner half rays only (Fig. 19,*7*). A form described as *Haeretocrinus intermedius* Strimple (1962) from the Holdenville Formation (Desmoinesian) of Oklahoma, which has the anal plates in Extreme Type (1) arrangement, is atypical of *Haeretocrinus* in having very short infrabasals and has been referred to *Tundracrinus* Yakovlev by Strimple. The cup is taller and more expanded than that typical of *Terpnocrinus,* but it has all the essential characteristics, and the second bifurcation of the arms takes place at secundibrachial *5* (Fig. 19,*5*). Further study may indicate this species should be placed in *Terpnocrinus.*

BIOMETRICAL DATA

ANAL SAC

The anal sac of typical *Terpnocrinus* is in the form of a massive looped tube, expanded at the summit and with the anal opening well down on the anterior side. Plates along the outer perimeter are relatively large, thick, and sharply keeled; in the interior, they are smaller, thinner, and lack pronounced surface extensions. The facets on the secundanal and tertanal plates were obviously for the purpose of tilting the anal sac, when the need arose.

The anal sac of *Haeretocrinus* is known only for *Haeretocrinus wagneri,* which species does not have a provision for tilting the sac. The sac has twice the height of the cup, is robust and looped, with heavy plates on the outer portion and small plates covering the interior of the loop. The anus is on the anterior side. There is a remarkable similarity in the anal sacs of *Terpnocrinus* and *Haeretocrinus,* except the latter often lacks means (confluent distal surfaces of secundanal and tertanal) of tilting the anal tube.

UNIVARIATE ANALYSIS

One of the most interesting features of the sample of *Terpnocrinus* from Nebraska is the observed size range of individuals, the dorsal cups ranging in diameter from 3.7 to 24.8 mm. The cups vary in height from 2.4 to 13.6 mm. Some of the smaller specimens are juveniles that have not attained all of the adult features (*see* Table 1).

BIVARIATE ANALYSIS

The chief disadvantage of univariate analysis is that it gives no information concerning morphological change during growth. This study of *Terpnocrinus* from Nebraska is based largely upon bivariate measures. Unlike the trilobites for which biometric analysis has been highly systematized (e.g., Shaw, 1956, 1957), crinoids have had no such system developed to facilitate their study. One of the long-term goals of this study is to develop such a system. The system, it is hoped, will not be so much a standard nomenclature for various measurements as it will be a set of guidelines for choosing meaningful pairs of measurements in analyzing ontogenetic and phyletic relations of each species of crinoid.

Scatter diagrams were prepared for nine pairs of dimensions listed in Table 2. The measure-

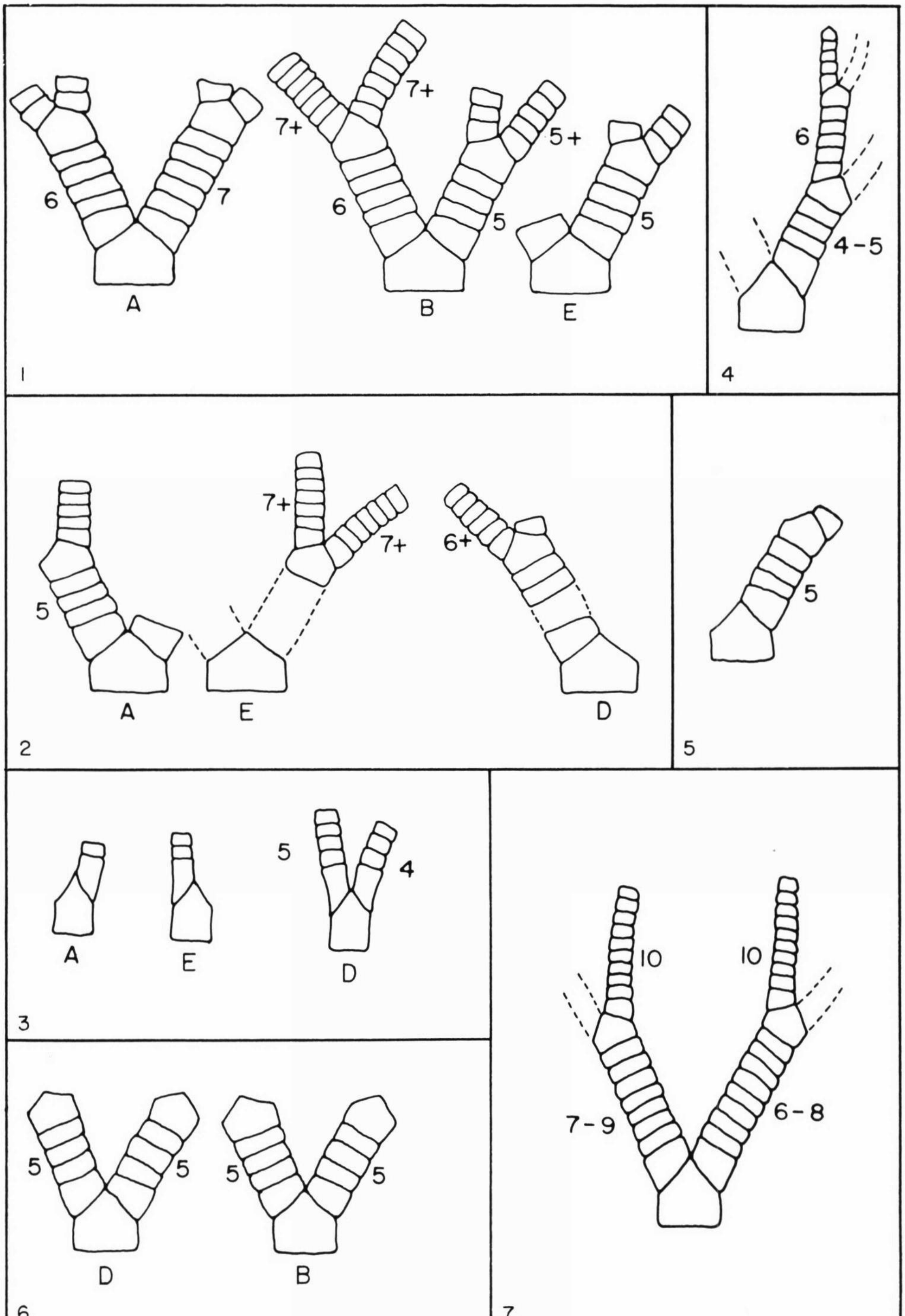

FIG. 19. *Terpnocrinus ocoyaensis* Strimple & Moore *(1,2)*; *T. ellipticus* Pabian & Strimple, n. sp. *(3)*; *Haeretocrinus turbinatus* Strimple *(4)*; *H. missouriensis* Moore & Plummer *(5)*; *H. turbinatus* Strimple *(6)*; *H. wagneri* Strimple & Moore *(7)* *(continued on facing page)*.

TABLE 1. *Univariate Measures Computed from Dorsal Cups and Plates of* Terpnocrinus ellipticus *Pabian & Strimple, New Species.* [All measurements in mm. Measurements as shown in Figure 20.]

DIMENSION	N	OBSERVED RANGE	MEAN	STANDARD DEVIATION
Height of cup, *H*	26	2.4-13.6	7.11	2.69
Diameter of cup (posterior-anterior), D_{PA}	25	3.6-24.8	11.10	5.133
Diameter of infrabasal circlet, D_{IBB}	25	1.2-9.3	4.67	5.00
Length of *EA* basal, L_{EA}	26	1.8-9.9	4.63	2.07
Width of *EA* basal, W_{EA}	26	1.5-10.2	4.55	4.97
Length of *A* radial, L_A	27	1.2-7.2	3.76	1.59
Width of *A* radial, W_A	27	2.1-13.3	5.74	6.32
Length of primanal, L_{RA}	26	1.3-8.3	4.01	4.39
Width of primanal, W_{RA}	26	1.3-8.5	3.89	4.29
Length of secundanal, L_{AX}	19	1.0-5.8	2.62	2.86
Width of secundanal, W_{AX}	19	0.3-6.0	2.63	1.25

TABLE 2. *Bivariate Measures Computed from Samples of* Terpnocrinus ellipticus *Pabian & Strimple, New Species.* [*R* = Total correlation coefficient. Symbols for paired dimensions as in Table 1 and Figure 20. Equations computed on basis of Nebraska sample only.]

PAIRED DIMENSION (Y, X)	N	R	REDUCED MAJOR AXIS EQUATION	SCATTER DIAGRAM	RATIO DIAGRAM
H, D_{PA}	25	.96	$H - .512D + 1.381$	Fig. 21	Fig. 22
D_{IBB}, D_{PA}	25	.96	$D_{IBB} + .338D_{PA} + .917$		
W_{EA}, L_{EA}	26	.99	$W_{EA} + .990L_{EA} + .037$	Fig. 27	Fig. 28
L_{EA}, L_A	26	.97	$L_{EA} + 1.191L_A + .157$		
W_{EA}, W_A	26	.99	$W_{EA} + .760W_A + .232$	Fig. 23	Fig. 24
W_A, L_A	27	.96	$W_A + 1.615L_A - .335$	Fig. 25	Fig. 26
L_{RA}, L_A	26	.92	$L_{RA} + .831L_A + .774$		
W_{RA}, W_A	26	.98	$W_{RA} = .695W_A - .187$		
L_{AX}, L_{RA}	19	.93	$L_{AX} + .680L_{RA} + .022$		

ments are indicated by the accompanying line drawings (Figure 20). In all cases, the general trend of the points is rectilinear; therefore, the dominant growth pattern for all dimensions investigated was isometric, indicating dimensions being compared were increasing at the same relative rate. The high correlation coefficients indicate the individual plates and dorsal cups of small individuals had essentially the same shapes as larger ones. The absence of distinct shape differences in individual plates and entire cups of *Terpnocrinus* suggests that the dorsal cup attained all its important morphological characteristics early in the life of the crinoid.

RATIOS BETWEEN VARIATES

The use of ratios between two dimensions has been a common taxonomic practice for many years. Some ratios, however, may be genuinely

FIG. 19. *(Continued from facing page.)*

1. *Terpnocrinus ocoyaensis* Strimple & Moore; *A, B,* and *E* rays of holotype, IGS 42P108.
2. *T. ocoyaensis* Strimple & Moore, *A, E,* and *D* rays of hypotype, UNSM 10032.
3. *T. ellipticus* Pabian & Strimple, n. sp.; *A, E,* and *D* rays of paratype, UNSM 9836.
4. *Haeretocrinus turbinatus* Strimple, from *B* ray of holotype (UNSM no. unknown).
5. *H. intermedius* Strimple, from *C* ray of holotype (OU 4172).
6. *H. missouriensis* Moore & Plummer, from the *D* and *B* rays of the holotype (Kansas City Public Library Coll., unnumbered).
7. *H. wagneri* Strimple & Moore, from the *A* ray of paratype (IGS 42P112).

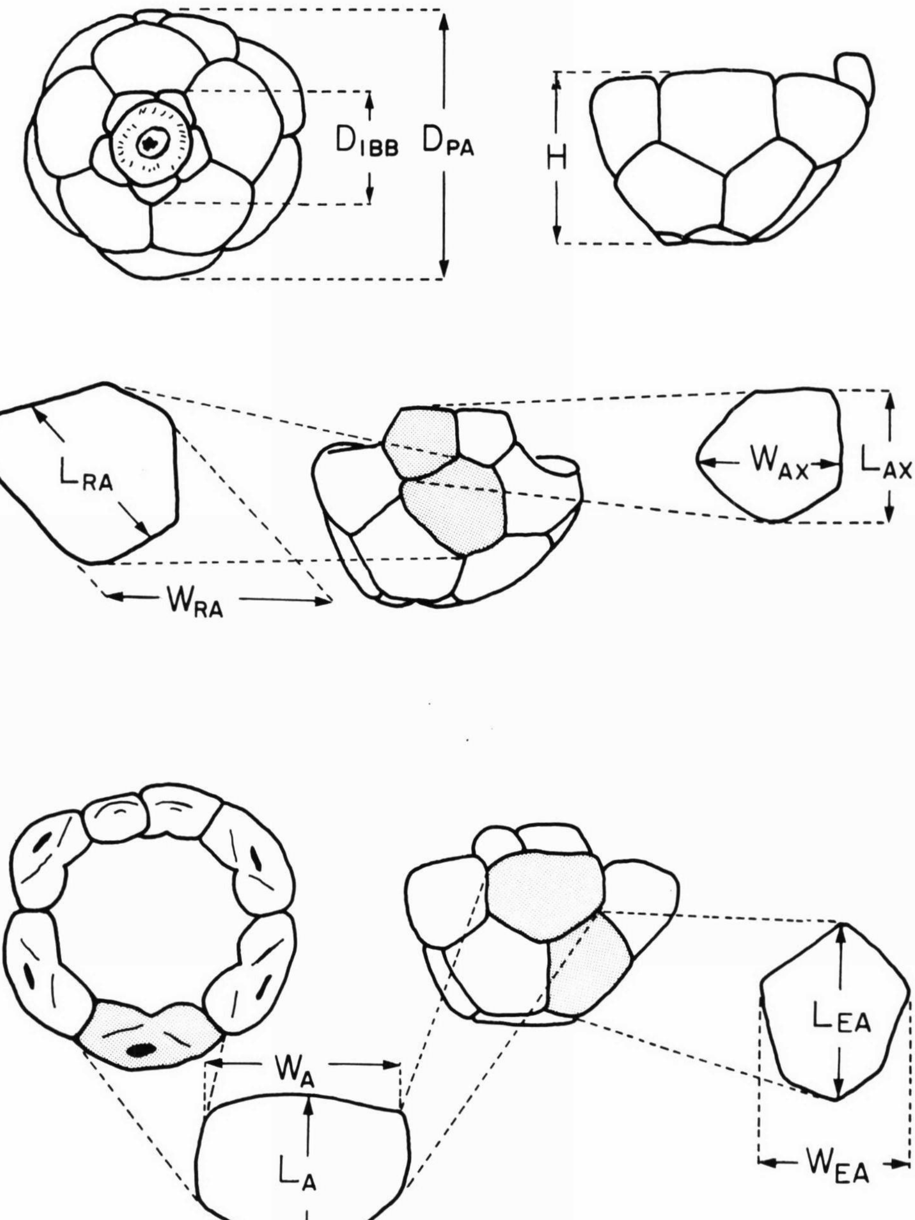

FIG. 20. Sketches of *Terpnocrinus ellipticus* Pabian & Strimple, n. sp., showing orientation of cup and illustration of dimensions taken and symbols used for those dimensions. [See Table 1 for explanation.]

unsuitable and each ratio used in taxonomy should be critically reviewed. The standard form of a linear equation is given by (i) $y = bx + a$, which may also be given by (ii) $\frac{y-a}{x} = b$. As the absolute value of a, $|a|$, approaches zero, the ratio y/x approaches b; that is, (iii) as $|a| \rightarrow 0$, $y/x \rightarrow b$. The greater the difference between the absolute value of a, $|a|$, and zero, the greater the difference in the ratio y/x and b. The biological significance of these mathematical concepts may be expressed as follows:

1. If growth is isometric, the greater the difference in the value of the initial growth index *(a)* and zero, the more the ratio y/x will change during growth.

2. The greater the variation in the value of the ratio between two dimensions (y/x), the less suitable it is as a taxonomic criterion (Shaw, 1956, p. 1212-1213).

3. The greatest variance in the ratio y/x occurs when these dimensions are small. Thus, the ratio between two dimensions may change considerably during early growth stages and have only limited significance, whereas the ratio may become relatively constant in later growth stages and become more significant.

These generalizations can be applied rather easily to a taxonomic understanding of *Terpnocrinus* from Nebraska. The absolute value of *A* in the reduced major axis equation for the diameter of cup to the anterior height of the cup is 1.381 (Fig. 21, 22). This means that in small specimens, less than about 7.0 mm in diameter, the ratio of height to diameter increases drastically as size decreases. The observed height/diameter ratios cluster fairly close to the predicted values (Fig. 22), except for the very smallest specimen where the observed height/diameter ratio is considerably less than its predicted value. The ratios, both predicted and observed, generally show the smaller cups to be higher and more conical than the larger.

Examination of the regression for comparing the width of the *EA* basal, W_{EA}, against the width of the *A* radial, W_A, indicates that the *A* radial was increasing in width somewhat faster than the *EA* basal (Fig. 23, 24). This would indicate that as the cup became larger, it opened up from a cone to a rounded bowl with a kind of blooming effect, material being added to the *A* radial faster than it was to the *EA* basal. In other words, the high, conical, juvenile cups become high, rounded, globose cups.

Comparison of observed to predicted width ratios for the *EA* basal, W_{EA}, and *A* radial, W_A (Fig. 24), shows the observed ratios for larger specimens fell closer to the predicted value than the observed ratios for small specimens. When the *A* radial is less than about 3.0 mm wide, the ratio of the width of the *EA* basal to the *A* radial increases considerably.

The rough data showed that cups having an *A* radial about 3.0 mm wide had a diameter of

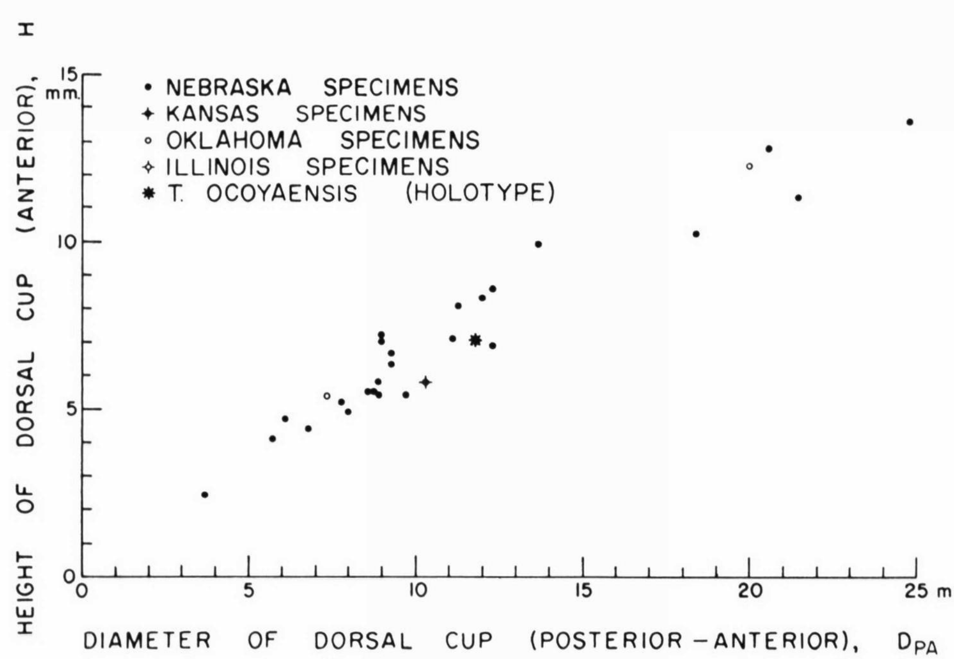

FIG. 21. Scatter diagram showing rectilinear growth for paired cup dimensions *H* and D_{PA} of *Terpnocrinus ellipticus*.

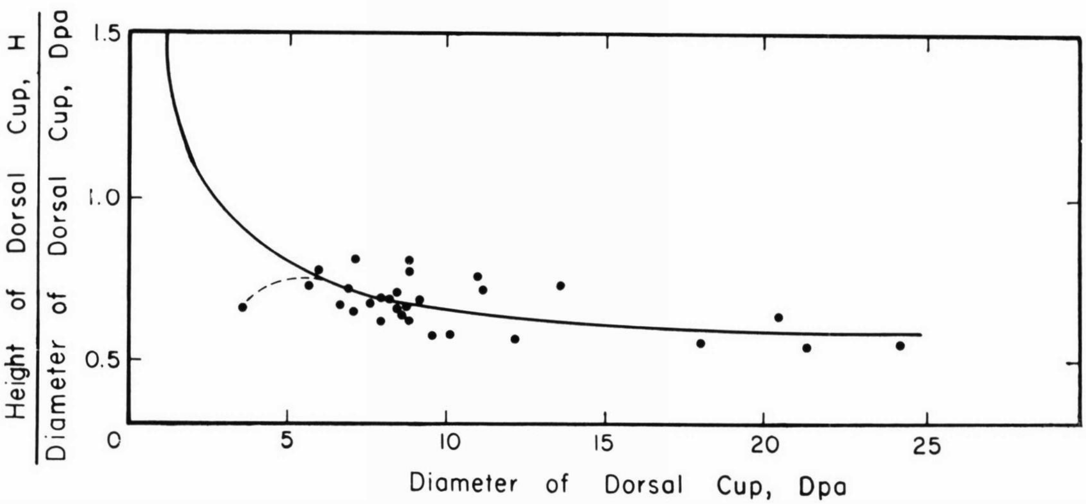

FIG. 22. Graph showing predicted and observed changes in the ratio H/D_{PA}.

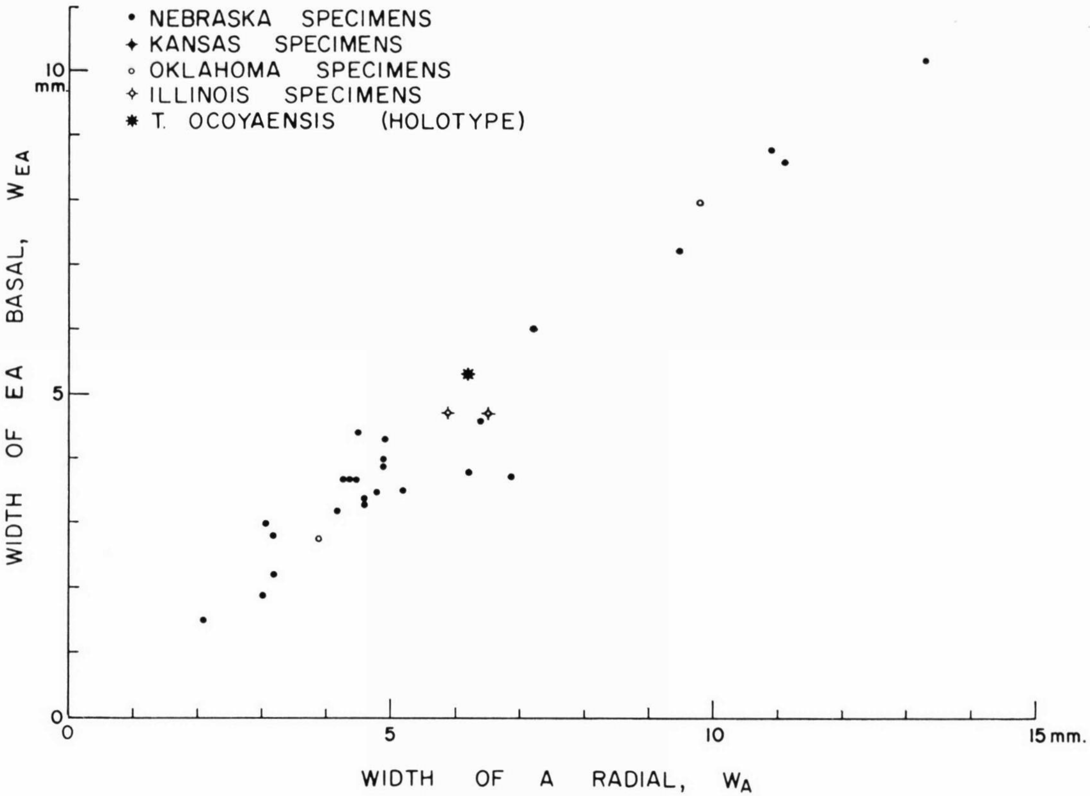

FIG. 23. Scatter diagram showing rectilinear growth for paired plate dimensions W_{EA} and W_A of *Terpnocrinus ellipticus*.

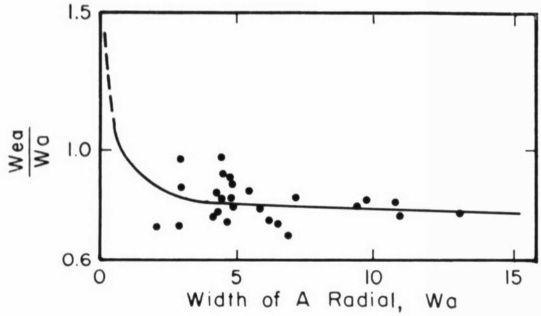

FIG. 24. Graph showing predicted and observed changes in the ratio W_{EA}/W_A.

about 7.0 mm—or the point below which the height to diameter ratio increases rapidly.

The observed-predicted ratio diagrams clearly show, especially where measurements are small, the variance of some ratios and their limitations as taxonomic criteria. Comparison of the ratio width for the *A* radial to length of the *A* radial, W_A/L_A (Fig. 25, 26), shows that specimens about 4.0 mm long varied from nearly 1.2 times

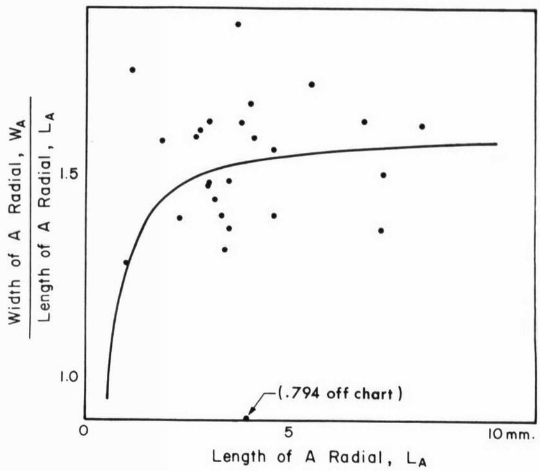

FIG. 26. Graph showing predicted and observed changes in the ratio W_A/L_A.

as wide to 0.7 times as wide. Such variation may be observed even visually. Fig. 26 clearly demonstrates that the width to length of the *A* radial is one of the most highly variable ratios of those observed.

The ratio comparing the width of the *EA* basal, W_{EA}, to the length of the *EA* basal, L_{EA}, is much less variable (Fig. 27, 28); and for small measurements of L_{EA} (*ca.* 2.0 mm), this ratio varies from about 0.8 to 1.0, the greatest variance

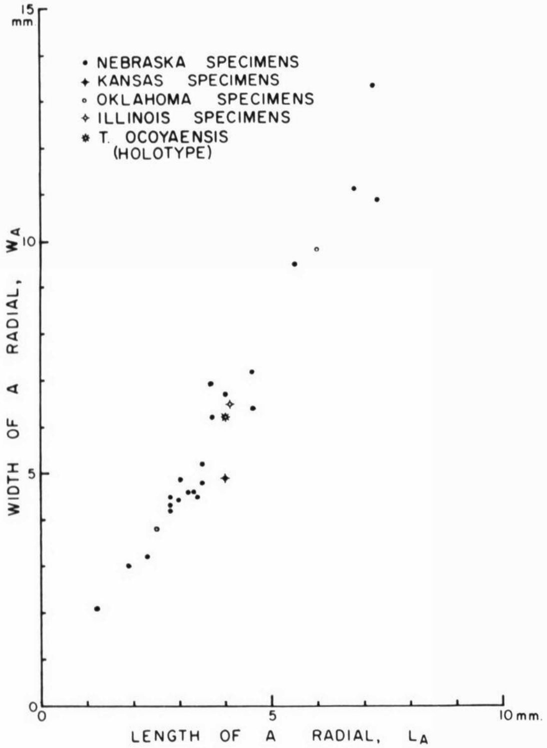

FIG. 25. Scatter diagram showing rectilinear growth for paired plate dimensions W_A and L_A of *Terpnocrinus ellipticus.*

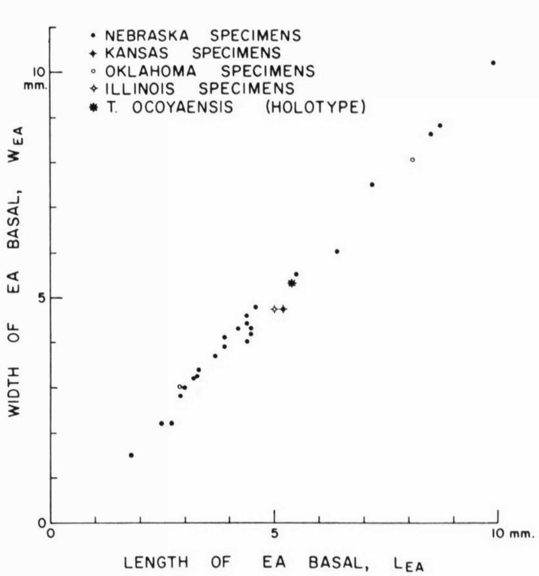

FIG. 27. Scatter diagram showing rectilinear growth for paired plate dimensions W_{EA} and L_{EA} of *Terpnocrinus ellipticus.*

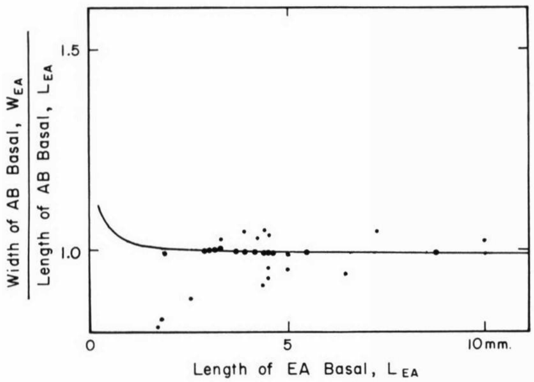

FIG. 28. Graph showing predicted and observed changes in the ratio W_{EA}/L_{EA}.

being observed where L_{EA} is very small. Thus, this ratio is a more suitable taxonomic criterion.

These ratio curves may, in a sense, also be survivorship curves. It may well be that the crinoid had to make its greatest adjustments of soft parts to plate morphology during the growth stage represented by the areas of greatest curvature on the ratio diagrams. Essentially, the hypothesis is that a lot of individuals enter this growth stage, but it is one of high mortality. The clustering of points representing measurements on small cups around the end-point of the area of greatest curvature on the predicted and observed ratio diagrams could even be indicative of a high mortality rate. This observation will be the subject of additional investigation.

QUALITATIVE MORPHOLOGY

The Nebraska species appears to be very closely related to *Terpnocrinus ocoyaensis* Strimple, from which it differs in having deeply incised sutures giving the plates a tumid or bulbous appearance, and in having a quadrangular rather than pentagonal secundanal plate. All the points for *Terpnocrinus ocoyaensis* that were plotted on the scatter diagrams, nine in all, fall among the point distribution for the Nebraska species. Thus, specific determination between *Terpnocrinus ellipticus* Pabian & Strimple, new species, and *T. ocoyaensis* Strimple & Moore is based on features that are not amenable to biometric treatment.

SYSTEMATIC DESCRIPTIONS

Phylum ECHINODERMATA Laske, 1778

Subphylum PELMATOZOA Leuckart, 1848

Class CRINOIDEA Miller, 1821

Subclass INADUNATA Wachsmuth & Springer, 1885

Order CLADIDA Moore & Laudon, 1943

Suborder POTERIOCRININA Jaekel, 1918

Superfamily AGASSIZOCRINACEA S. A. Miller, 1890

Family ANOBASICRINIDAE Strimple, 1961

Diagnosis.—Dicyclic; expanded crown. Cone-shaped or truncate cone-shaped dorsal cup. Infrabasals five, upflared or subhorizontal; basals five; radials five with articular facets almost or entirely filling summit of plate; anal plates three, primitive to advanced. Arms long, uniserial, pinnulate, with rounded exterior branching endotomous, heterotomous or exotomous, primibrach *1* axillary in all rays. Large, recurved anal sac which may become bulbous or balloon-shaped.

Genera.—*Anobasicrinus* Strimple, 1961; *Synyphocrinus* Trautschold, 1867; *Terpnocrinus* Strimple & Moore, 1971.

Genus TERPNOCRINUS Strimple & Moore, 1971

Type Species.—*Terpnocrinus ocoyaensis* Strimple & Moore, 1971, p. 23-24, fig. 8; pl. 14, fig. 1a-d.

Other Species Included.—*Terpnocrinus ellipticus* Pabian & Strimple, new species.

Diagnosis.—See Strimple & Moore, 1971, p. 23-24.

Remarks.—Moore & Strimple (1973, p. 21) have placed *Terpnocrinus* in the Cromyocrinidae. Both of the present authors disagree with this assignment. The anal sac of *Terpnocrinus* appears to be too well developed to be that of a cromyocrinid. Though Strimple and Moore compare *Terpnocrinus* to *Goleocrinus,* the latter has a concave base and a decidedly shallower cup. In addition, the arms of *Terpnocrinus* are more closely comparable to *Haeretocrinus* than to those of any cromyocrinid.

Occurrence.—Upper Pennsylvanian (Missourian), USA (Oklahoma, Kansas, Nebraska, Illinois, Texas).

TERPNOCRINUS ELLIPTICUS Pabian & Strimple, new species

Figures 19, *3*; 20-29; 30, *1*

Description.—The dorsal cup is conical in young individuals, becoming more globose as size increases. Small individuals have "dimples" or depressions at the plate junctions, these depressions becoming less distinct as size increases, finally being absent on some larger specimens. Sutures between cup plates are distinct and somewhat impressed on all cups, regardless of ontogenetic position.

The infrabasal circlet consists of five small, kite-shaped plates. The crenulated stem impression has a round lumen and may almost cover the entire infrabasal circlet on some specimens, only the distal tips of the infrabasals being visible. On other specimens the columnar cicatrix may cover only about half the infrabasal circlet, the distal ends of the upflared infrabasals making the proximal portions of the cup walls.

The *AB, CD, DE,* and *EA* basals are shield-shaped and rise at about a 45-degree angle to about two-thirds the height of the cup. The distal tips of the basals are nearly vertical. The *BC* basal is heptagonal, the upper left corner being truncated for the reception of a six-sided primanal that is bounded below by the upper right shoulder of the *CD* basal, and upper left shoulder of the *BC* basal.

The *A, B, D,* and *E* radials are epaulette-shaped. The *D* radial has an extra side facet and laterally bounds the primanal and secundanal. The *C* radial, though pentagonal, is irregular in shape in order to accommodate the primanal below and the tertanal plate left-laterally. The radials are much more swollen on larger specimens than on small, causing the large cups to show well-developed, deep notches at the interradial sutures.

The secundanal is an irregular pentagon, bounding the *D* radial and primanal below and the tertanal laterally. The tertanal also is an irregular pentagon that bounds the primanal and *C* radial below.

The cup plates are smooth or very finely frosted. Sutures are distinct and somewhat impressed, though cup plates, except for larger specimens, show little tendency toward becoming bulbous.

The radial plates increase in width somewhat faster than basals during ontogeny, such that small cups are conical in cross section, whereas large cups are much more globose. The radial plates also increase in width somewhat faster than does the primanal.

The radial-articulating facets are plenary, occupying the entire width of the radials; they slope outward only slightly. The outer marginal ridges are defined by a sharp incurvation at the summit of the cup. The outer ligament furrow is nearly non-existent and there is only a very fine outer ligament ridge that is bordered by a row of fine denticles extending the width of the radial facets; the ligament pit is deep and well defined. The oblique furrow is shallow on the side of the transverse ridge but bounded interiorly by a very high, slightly denticulate oblique ridge. Muscle areas are large and slope inward to a deep, narrow, elongated central pit that connects to an intramuscular notch by a very narrow, well-defined intramuscular furrow. The lateral ridges are sharply defined, relatively high. Lateral slopes recurve inward near the interior of the cup. There are deep notches at the radial sutures.

The five axillary primibrachials are epaulette-shaped plates. Their length-width ratio decreases considerably in larger specimens. The secundibrachials are nonaxillary, *SBr1* being about twice as long as four succeeding secundibrachs at least on the *D* ray of one juvenile specimen.

Measurements.—See Appendix I.

Material Studied.—Holotype SUI 36247, paratypes SUI 36248, SUI 37650-SUI 37654, UNSM 9843, UNSM 9844, Kiewitz Shale zone, Stoner Limestone Member, Stanton Formation, Lansing Group, Missourian Stage (Upper Pennsylvanian); Rock Lake Quarry, NE ¼, SW ¼, sec. 3, T. 12 N., R. 10 E., Sarpy County, Nebraska. Paratypes SUI 36245, SUI 36246, SUI 37655-SUI 37661, Kiewitz Shale zone, Ash Grove Cement Company Quarry, NE ¼, NE ¼, sec. 19, T. 12 N., R. 11 E.,

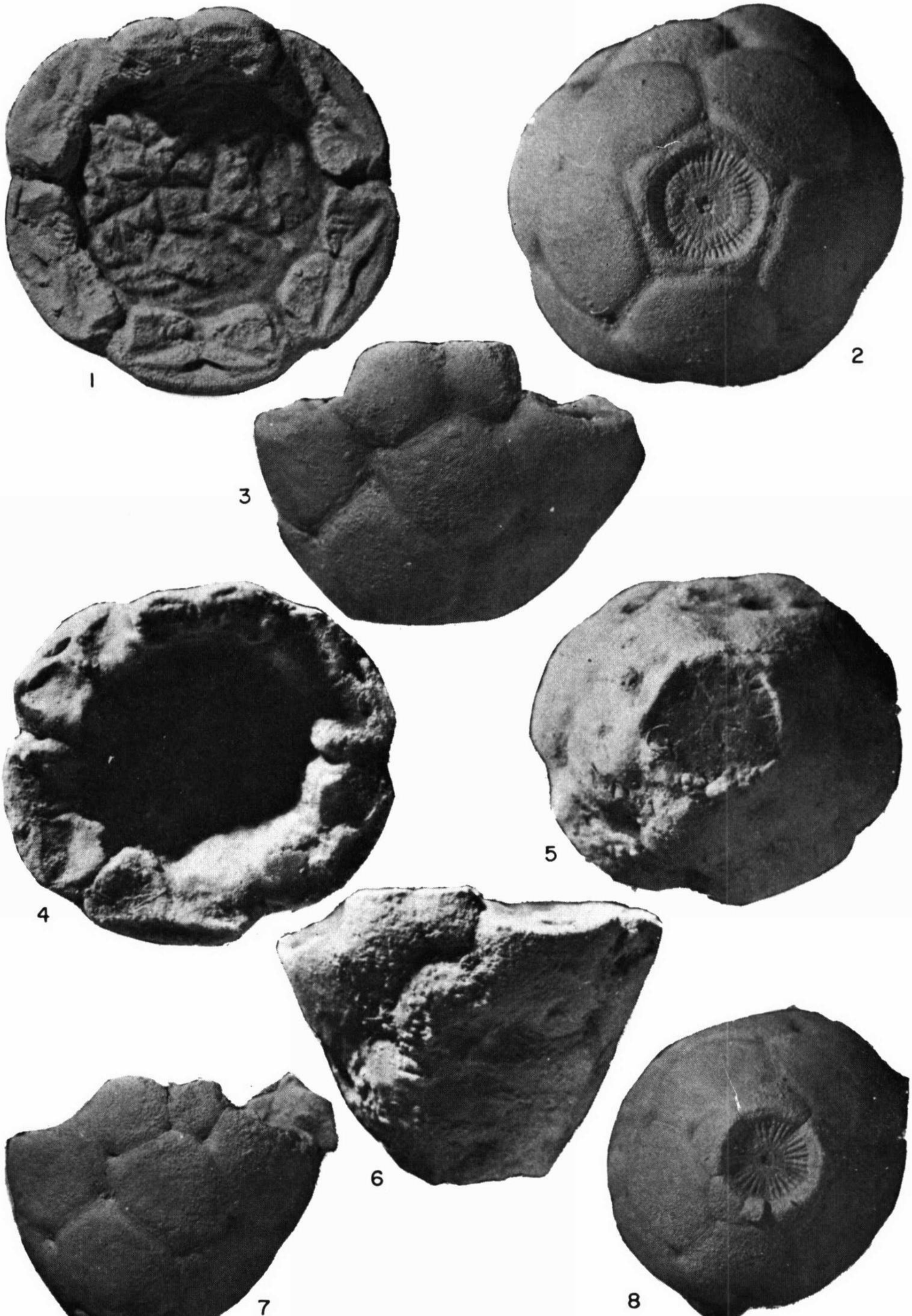

FIG. 29. *Terpnocrinus ellipticus* Pabian & Strimple, n. sp.——*1-3*. Ventral, dorsal, and posterior views of holotype, SUI 36247, ×3.——*4-6*. Ventral, dorsal, and posterior views of paratype, UNSM 9837, ×10.——*7-8*. Posterior and basal views of paratype, SUI 36245, ×3.

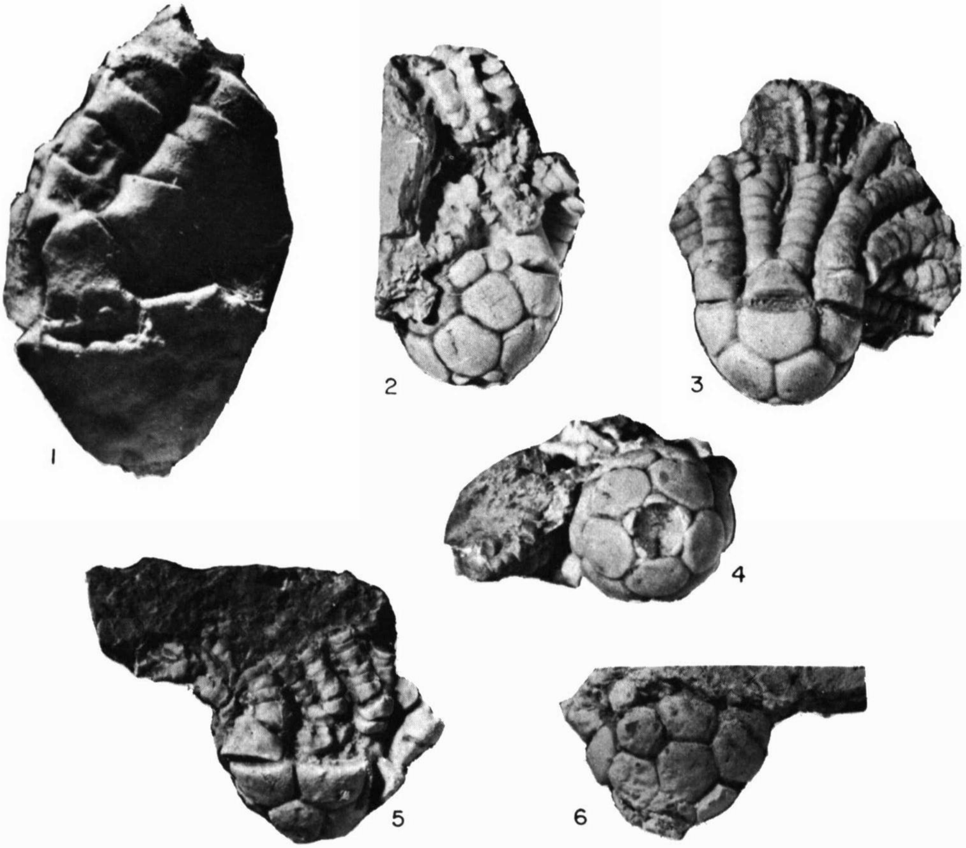

FIG. 30. *Terpnocrinus ellipticus* Pabian & Strimple, n. sp. *(1)*; *Terpnocrinus ocoyaensis* Strimple & Moore *(2-6)*.——*1*. *T. ellipticus* Pabian & Strimple, n. sp., posterior view of immature, partial crown, UNSM 9836, ×10.——*2-4*. *T. ocoyaensis* Strimple & Moore, posterior, anterior, and dorsal views of holotype, IGS 42P108, ×1.5.——*5,6*. *T. ocoyaensis*, anterior and posterior views of topotype, UNSM 10032, ×2.

Cass County, Nebraska. Paratypes SUI 37665, SUI 37666, UNSM 9836, UNSM 9837, UNSM 9849, Kiewitz Shale zone, Derby Quarry, SE ¼, NE ¼, sec. 16, T. 12 N., R. 11 E., Cass County, Nebraska. Paratypes SUI 37662-SUI 37664, Kiewitz Shale zone, Old Burlington Quarry, SW ¼, SW ¼, sec. 11, T. 12 N., R. 16 E., Cass County, Nebraska. Paratype SUI 37667, Atwood Quarry, NE ¼, SW ¼, sec. 18, T. 12 N., R. 12 E., Cass County, Nebraska. Hypotype SUI 37669, Stoner Limestone Member, Stanton Formation, Lansing Group, Missourian Stage, Upper Pennsylvanian, exposures along Fish Hatchery Road, NE ¼, NW ¼, sec. 16, T. 12 N., R. 11 E., Sarpy County, Nebraska. Hypotype UNSM 10031, Upper part of Stanton Formation, NE ¼, sec. 18, T. 29 S., R. 16 E., Wilson County, Kansas. Hypotypes SUI 36249, SUI 36250, Wann Formation, Ochelata Group, Missourian Stage, the Mound, Bartlesville, Oklahoma. Hypotype SUI 37668, Wolf Mountain Shale Member, Graford Formation, Missourian Stage (Upper Pennsylvanian), Lake Bridgeport, Wise County, Texas.

Remarks.—*Terpnocrinus ellipticus* differs from *T. ocoyaensis* largely in the nature of the plates and sutures between the plates, the latter species having large, bulbous plates and very deeply impressed sutures. Sutures of the former species are distinct but not deeply impressed. Further, the secundanal of *T. ocoyaensis* is quadrangular, whereas it is pentagonal in *T. ellipticus*.

TERPNOCRINUS OCOYAENSIS Strimple & Moore, 1971

Figure 19, *1, 2*; 30, *2-6*

Terpnocrinus ocoyaensis Strimple & Moore, 1971, p. 23, 24, pl. 14, fig. 1a, d; fig. 8.

Remarks.—A partial crown of this species qualifies as a topotype specimen; it was collected by the senior author from the type locality in the summer of 1968, some time after the original LaSalle crinoid fauna was discovered and collected. The arm structure of this specimen is shown by Figure 30,*5,6*.

Terpnocrinus ocoyaensis appears to be very closely related to *T. ellipticus*, the major differences being in the shape of the secundanal plate and the degree of impression of the sutures.

The nature of the sediments enclosing the specimens of *Terpnocrinus ocoyaensis* and *T. ellipticus* suggests that the former lived in perhaps somewhat more quiet waters than the latter. Strimple & Moore (1971, p. 5, fig. 2) indicated that the LaSalle crinoid fauna, from which the type of *Terpnocrinus* was collected, represent quiet water sedimentation in local areas where clayey sediment predominated over calcareous deposits. These were laid down in quiet water without perceptible wave or current action which would have disturbed the crinoid skeletal elements before or during their burial.

Burchett & Reed (1967, p. 38) indicated deep to shallow, disturbed to quiet water conditions, with low to moderate argillaceous and siliceous contributions, predominated during the deposition of the Stoner Limestone of which the Kiewitz Shale zone forms parts of the basal unit.

The specimen of *Terpnocrinus ellipticus* from southern Kansas was collected from one of the marine banks as described by Harbaugh *et al.* (1965). Wray (1965, p. 47-53) indicated that the algae in these banks were of the genus *Archeolithophyllum* which was a red, either encrusting or free, alga; their thalli provided a sediment-binding function. *Archeolithophyllum* most commonly inhabited the inner sublittoral marine environment and was able to tolerate appreciable wave agitation, though it may have ranged to depths of up to 100 feet.

The sedimentological evidence of the rocks enclosing *Terpnocrinus ocoyaensis* and *T. ellipticus* may indicate that the former species preferred quiet waters, whereas the latter was able to tolerate even moderate wave action.

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ADDENDUM

MORPHOLOGICAL TERMS FOR ANAL PLATES

The terms used for designation of anal plates located in the posterior interray of the cup are those adopted in Moore & Strimple (1973, p. 12, 13). The lowermost anal plate was termed primanal, next higher secundanal, etc. Where three anal plates are present the lowermost is primanal (radianal), followed by secundanal (anal *X*) to the left and tertanal (right tube plate) to the right. In most instances we have shown both the old and new terms. Further discussions between authors of Part T of the *Treatise* has led to abandonment of the new designations, and the term primanal is now restricted to camerate crinoids; however, the present series of papers were already in press and so the terminology has not been changed.

APPENDIX I

Measurements (in mm.) of Holotype, Specimens of New Species of Crinoids Described in Parts 1-4.
[Symbols for dimensions as in Figure 20 and Table 1, Part 4.]

SPECIES	H	D_{PA}	D_{IBB}	L_{EA}	W_{EA}	L_A	W_A	L_{RA}	W_{RA}	L_{AX}	W_{AX}
PART 1											
Plaxocrinus macrospiniferus, UNSM 10412	7.5	26.8	9.0	8.2	10.2	7.8	16.5	7.2	4.7	7.2	5.3
Aglaocrinus supplantus, UNSM 10417	13.1	26.5	7.0*	13.0*	14.4	9.0*	14.8	6.2	8.5	4.7	3.1
PART 2											
Paradelocrinus thurmanensis, UNSM 10152 (Length of crown, 50.0 mm)	7.1*	..	4.3	8.5	8.8	..	..	..	..	..	..
Scytalocrinus fremontensis, UNSM 10164 (Length of crown, 55.0 mm)	6.4*	19.0*	4.9*	4.2	4.5	4.5	9.5	6.2	4.1	..	..
Glaukosocrinus forneyi, UNSM 10168	4.5*	..	..	3.4	..	..	..	..	2.5	3.2*	2.0*
PART 3											
Paradelocrinus burdeni, UNSM 10398	7.2	23.0*	3.5	..	9.2	..	13.5	..	..	..	..
PART 4											
Terpnocrinus ellipticus, SUI 36247	13.4	18.2	7.2	7.2	7.5	5.5	9.5	6.5	6.1	4.7	4.9

* Estimated