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FOSSIL CRINOID STUDIES

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CONTENTS

PART 1

THE FAMILY DIPHUICRINIDAE

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ABSTRACT

The present study is for the purpose of stabilizing the family Diphuicrinidae STRIMPLE & KNAPP, 1966. The lineage is first known from the Bloyd Formation, Lower Pennsylvanian (Morrowan), of Oklahoma and Arkansas. *Parallelocrinus* KNAPP, 1969, from the Burgner Formation, Lower Pennsylvanian (Atokan), of Missouri, is placed in synonymy with *Diphuicrinus* MOORE & PLUMMER. *Wewokacrinus* KNAPP, 1969, from the Wewoka Formation, Middle Pennsylvanian (Desmoinesian), of Oklahoma, is placed in synonymy with *Delocrinus* MILLER & GURLEY. New taxa described are *Diphuicrinus coalensis* STRIMPLE & MOORE, n. sp., Barnett Hill Member, Atoka Formation (Atokan), Oklahoma; *D. dovelyensis* STRIMPLE & MOORE, n. sp., Dovely Limestone and Deese Formation (Desmoinesian), Oklahoma; *D. pegmus* STRIMPLE & MOORE, n. sp., Frensley Limestone (Desmoinesian), Oklahoma; and *Atokacrinus decorus* STRIMPLE & MOORE, n. sp., Lester Formation (Desmoinesian), Oklahoma.

INTRODUCTION

The genus *Diphuicrinus* MOORE & PLUMMER, 1938, was erected on the basis of dorsal cups from the Bloyd Formation, Lower Pennsylvanian (Morrowan) of Oklahoma and Arkansas. Infrabasal plates were covered by dense matrix and preparation of the specimens disclosed only three sutures in the circlet. Specimens subsequently collected by STRIMPLE, *et al.*, demonstrated the existence of five infrabasals, in downflared position, as reported by STRIMPLE & KNAPP (1966, p. 312). Reexamination and preparation of the holotype of *D. croneisi* also revealed the presence of five infrabasals. Specimens from the Wapanucka Formation (Morrowan) of southern Oklahoma were referred to *D. croneisi* MOORE & PLUMMER, 1938, type-species of the genus.

The arms of *Diphuicrinus* are known from a young but mature crown of *D. croneisi* illustrated by STRIMPLE & KNAPP (*ibid.*, pl. 36, fig. 1-2). They are long, slender, branched on primibrach *1* in all rays and are uniserial, albeit the brachials are cuneiform. All of the crown is covered by coarse nodes and granules.

KNAPP, 1969, in a study based primarily on dorsal cups from the Burgner Formation (Atokan) of Missouri, proposed Declinida, a new order of late Paleozoic inadunate crinoids. The proposal has been rejected by LANE (1971) and does not concern us directly here other than to state our agreement with the rejection. Four genera proposed by KNAPP, 1969, do affect the present study: *Palmerocrinus, Parallelocrinus, Atokacrinus,* and *Wewokacrinus*. For some reason KNAPP almost completely ignored *Diphuicrinus* and did delete the family Diphuicrinidae STRIMPLE & KNAPP, 1966. The genus was acknowledged by KNAPP (*ibid.*, text-fig. 3) but more as an afterthought expressed as "*?Diphuicrinus*-like ancestor," to *Parallelocrinus*.

Diphuicrinus is thought to have evolved from a form like *Phanocrinus irregularis* STRIMPLE, 1951, which species has a granulose surface and an advanced arrangement of anal plates in the *CD* interray wherein the radianal has moved to a dominant posterior position but is considerably reduced in size as though in the process of re-

sorption (see STRIMPLE, 1960, text-fig. 1d). The arms of *P. irregularis* are equiuniserial, whereas those of *Diphuicrinus croneisi* are almost interlocking.

An elongated anal plate (anal *X*), which slopes inward at a low angle, is a common feature among specimens of Morrowan *Diphuicrinus* (Fig. 1,*1*); however, in some specimens the anal plate is not appreciably elongated. The distal surface of anal *X* in many Morrowan specimens is faceted for reception of a single tube plate, but some specimens are faceted for two tube plates. *D. patina* STRIMPLE & KNAPP, 1966, from Magoffin beds, Breathitt Formation of Kentucky, has a long, narrow, distally sloped anal plate (Fig. 1,5). It thus appears that two slightly divergent forms within *Diphuicrinus* developed in Morrowan time. Post-Morrowan forms with an elongated anal plate projected at a low angle are retained in the genus *Diphuicrinus*. Post-Morrowan crinoids having ornate surfaces with an erect distal end about equal in length to the proximal end of the anal *X* and followed by a single tube plate are referred to *Graffhamicrinus* STRIMPLE (1961). It may be found that some older forms, having ornate surfaces and an erect anal plate, do not have biserial arms typical of *Graffhamicrinus,* in which case retention in *Diphuicrinus* is recommended.

Typical *Delocrinus,* as represented by the proposed fixation of a neotype of *Poteriocrinus hemisphericus,* type-species of *Delocrinus,* by MOORE & STRIMPLE (1970, pl. 4), has a long anal plate, sloping at a rather low angle and one specimen (*ibid.,* pl. 4, fig. 2) has facets for two tube plates with the smaller facet to the lower right (left in view from summit). The forefacet at summit of radials, typical of *Diphuicrinus,* is essentially absent in *Delocrinus* and the distal end of anal *X* has a higher angle, but close relationship between the two genera is thought to exist. It is not clear at this time whether *Delocrinus* evolved directly out of phanocrinid stock or through the diphuicrinids, but in any event it is thought to belong to the Diphuicrinidae.

The genus *Wewokacrinus* KNAPP (1969, p. 361) is placed in synonymy with *Delocrinus*. The monotypic species ascribed to *Wewokacrinus, Delocrinus wewokaensis* STRIMPLE, 1940, lacks the surface ornamentation and pronounced radial forefacet typical of *Diphuicrinus* and the distal end of anal *X* has a relatively higher angle to horizontal. All of those characters are found in the neotype of *Delocrinus hemisphericus.*

KNAPP (1969) proposed two new genera from the Burgner Formation (Atokan) of Missouri which have the characteristics of *Diphuicrinus. Parallelocrinus* KNAPP (*ibid.,* p. 360) is considered here to be a synonym of *Diphuicrinus.* It has a very rugose surface which is reflected at the summit of the cup by a pronounced flattened shelf to the fore of the outer ligament area, both of which characters are held in common with *Diphuicrinus. Palmerocrinus* KNAPP (1969, p. 360) lacks the pronounced ornate surface and the foreshelf at cup summit, except for one paratype (UM14805) of *P. comptus* KNAPP (*ibid.,* pl. 61, fig. 22-24; see Fig. 1,2 herein). The specimen is so similar to *Parallelocrinus typus* KNAPP (*ibid.,* pl. 61, fig. 10-12) (see Fig. 1,5 herein) that it is considered here to be conspecific with *P. typus*=*Diphuicrinus typus* (KNAPP), n. comb.

SYSTEMATIC DESCRIPTIONS

Family DIPHUICRINIDAE Strimple & Knapp, 1966

DIAGNOSIS.—Bowl-shaped dorsal cup with deep basal invagination; infrabasals five, steeply downflared; one anal plate followed by either one or two tube plates; arms ten, uniserial in older forms to biserial; surface of cup and all or part of arms covered by pustules and or granules; stem round.

GENERA CONSIDERED HEREIN.—*Diphuicrinus* MOORE & PLUMMER, 1938; *Atokacrinus* KNAPP, 1969; *Graffhamicrinus* STRIMPLE, 1961; *Palmerocrinus* KNAPP, 1969.

OCCURRENCE.—Pennsylvanian to Lower Permian; USA.

Genus DIPHUICRINUS Moore & Plummer, 1938

TYPE-SPECIES.—*Diphuicrinus croneisi* MOORE & PLUMMER, 1938.

DIAGNOSIS.—Distal portion of anal plate elongated, at low angle to horizontal, usually faceted for two tube plates; pronounced forefacet near summit of radials; arms uniserial (cuneate brachials), ornate, rounded outer surfaces; surface ornamentation pustulose and granular.

OCCURRENCE.—Pennsylvanian (Morrowan to Desmoinesian); USA (Oklahoma-Arkansas).

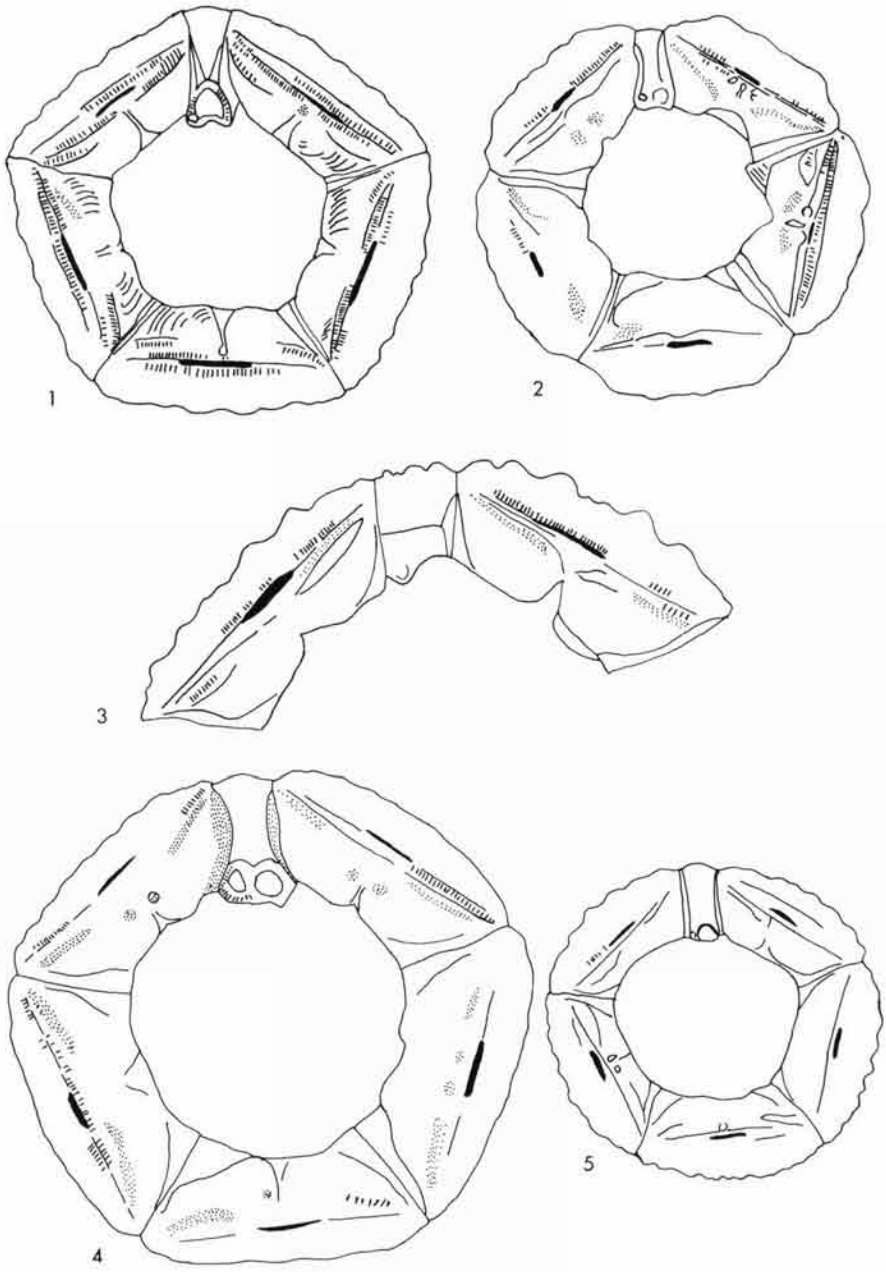

FIG. 1. Camera lucida drawings of various diphuicrinids viewed from summit, all ×2.7.

1. *Diphuicrinus dovelyensis* STRIMPLE & MOORE, n. sp., paratype OU 6448, Lower Deese Fm., Okla.
2. *D. typus* (KNAPP), n. desig. (USNM144982) described as paratype of *Palmerocrinus comptus*, Burgner Fm., Mo.
3. *D. croneisi* MOORE & PLUMMER, hypotype (OU 7121), Bloyd Fm., Okla.
4. *D. typus* (KNAPP), n. comb. (UM14805), holotype, Burgner Fm., Mo.
5. *D. patina* STRIMPLE & KNAPP (SUI11900), holotype, Magoffin Beds, Ky.

DIPHUICRINUS PEGMUS Strimple & Moore, n. sp.
Figure 2,*4-6*

DESCRIPTION.—Dorsal cup shallow, bowl-shaped, proximal portions of radials form part of basal plane of cup, basal concavity broad and rather deep, infrabasals missing, but rather certainly downflared, surface covered by moderately large pustules and granules, prominent subhorizontal forefacet beyond outer ligament area. Radial articular facets are distinctive. The transverse ridge is denticulated and joined to the fore by a denticulated outer ridge so that the rather short ligament pit is completely surrounded; intermuscular notch is small, the furrow very narrow and bordered on each side by narrow furrows; central pit small and flanked on each side by a pit; lateral furrows are well-defined and terminate near the intermuscular notch with a pit on each side of the intermuscular furrow; muscle areas rather restricted; adsutural areas very narrow except toward body chamber where they widen; prominent flattened forefacet well below outer ligament area. Anal plate long, narrow, extended toward body chamber where it flares slightly at an angle low to horizontal, 2 rounded facets for reception of tube plates, smallest to the right.

DISCUSSION.—Radial articular facets and surface ornamentation of *Diphuicrinus pegmus* suggest close affinity with *Atokacrinus decorus*.

Measurements of Holotype in Millimeters

Width of cup posteroanterior and maximum	15.0, 15.2
Height of cup	5.5
Width of infrabasal circlet	3.3
Width and length of *AE* basal	5.0, 6.0*
Width of *CD* basal	6.0
Width of *B* radial	9.0
Length of *B* radial (to transverse ridge)	6.8*
Width and length of anal *X*	1.9, 3.0
Diameter of proximal columnal	1.3

* measurements taken along surface curvature.

HOLOTYPE.—OU6444, collected by ALLEN GRAFFHAM.

OCCURRENCE.—Frensley Limestone, Pennsylvanian (Desmoinesian), center south line NE¼, sec. 30, T.4S., R.2E., Carter County, Oklahoma.

DIPHUICRINUS COALENSIS Strimple & Moore, n. sp.
Figure 2,*9-14*

DESCRIPTION.—Dorsal cup low bowl-shaped; infrabasals downflared, confined to basal concavity; basals large, wide; proximal portions of radials in basal plane, distal portions flexed inward to form forefacet, articular facets horizontal, transverse ridge and outer ligament ridge denticulated, joined except for area occupied by deep ligament pit, lateral furrows closely adjoining transverse ridge, adsutural areas very narrow; anal *X* narrow, elongated, extended to body chamber at low angle to horizontal, distal end flared and occupied by 2 facets for reception of tube plates, smaller being to the right. Proximal columnal smaller than area impressed for its reception, round, short crenulations reach outer edge, lumen round. Anal tube and arms unknown.

Measurements of Holotype in Millimeters

Width of cup posteroanterior and maximum	22.8, 23.1
Height of cup	5.8
Width of infrabasal circlet	5.2
Width and length of *AE* basal	9.0, 10.0*
Width of *CD* basal	8.2
Width of *B* radial	13.5
Length of *B* radial (to transverse ridge)	9.1*
Width and length of anal *X*	2.2, 5.2*
Diameter of proximal columnals	2.3

* measurements along surface curvature

TYPES.—Holotype, OU6445. Hypotype OU6446. Collected by ALLEN GRAFFHAM.

OCCURRENCE.—Holotype, Barnett Hill Member, Atoka Formation, Pennsylvanian (Atokan); SW ¼, sec. 23, T.1N., R.8E., Coal County, Oklahoma. Hypotype, 100 ft. above Gene Autry Shale (Morrowan), Atokan (?) Stage, Pennslyvanian; NW ¼, SW ¼, sec. 2, T.4S., R.4E., Johnson County, Oklahoma.

DIPHUICRINUS DOVELYENSIS Strimple & Moore, n. sp.
Figures 1,*1*; 2,*7-10*; 3,*1-4*

DESCRIPTION.—Dorsal cup low, bowl-shaped with evenly rounded contour even in the broad basal concavity; infrabasals 5 slightly downflared; basals relatively broad; proximal ends of radials reach or participate in basal plane, distal ends curved inward slightly and form a sloped forefacet, denticulated outer ligament ridge is separated from transverse ridge, ligament pit rather short, lateral furrows just behind transverse ridge, oblique ridges denticulated, intermuscular notch and furrow well defined, muscle areas rather large; anal *X* elongated, distal portion at

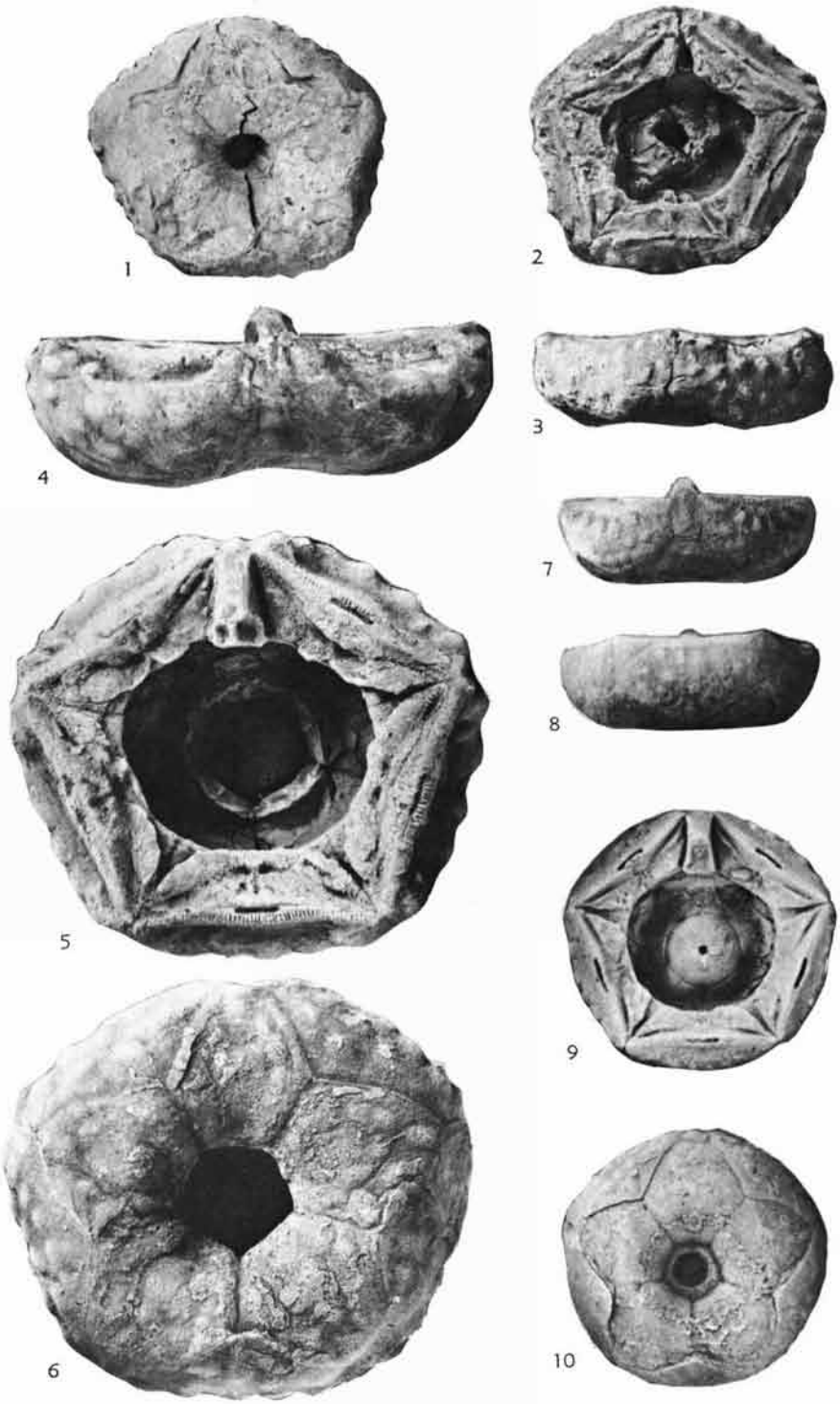

FIG. 2. *Atokacrinus and Diphuicrinus* from Oklahoma. *(Continued on facing page.)*

low angle extending into body cavity, faceted for reception of 2 tube plates, smaller facet to the right. Columnar attachment cicatrix small, sharply impressed. Radials marked by low nodes and very fine granulations, basals with random faint swellings. Anal tube and arms unknown.

Discussion.—The broad, relatively shallow basal concavity with mildly downflared infrabasals and evenly rounded cup serve to distinguish *Diphuicrinus dovelyensis* from most species of the genus.

Measurements in Millimeters

	Holotype OU6447	Paratype OU6448
Width of cup—maximum	24.1	23.0
Width of cup—posteroanterior	23.0	22.2
Height of cup	13.2	7.3
Width of infrabasal circlet	5.0	4.9
Width of *AE* basal	10.0	8.7
Length of *AE* basal	12.0*	10.8*
Width of *CD* basal	10.0	8.7
Width of *B* radial	13.2	12.9
Length of *B* radial (to transverse ridge)	9.8*	10.0*
Length of anal *X*	4.8*	7.0*
Width of anal *X*	3.4	2.6
Diameter of proximal columnal	2.0	2.3

* measurements along surface curvature

Types.—Holotype OU6447 (Dovely Limestone), collected by C. A. Branson, paratypes OU6448, OU6448A (Deese Formation), collected by Allen Graffham.

Occurrence.—Dovely Limestone, Savanna Formation, Middle Pennsylvanian (Desmoinesian); SW corner SW ¼, NW ¼, sec. 25, T.21N., R.17E., Rogers County, and Deese Formation (Desmoinesian), sec. 29, T.3S., R.2E., Carter County, Oklahoma.

DIPHUICRINUS sp.
Figure 2,*9-11*

Description.—Basal invagination is smaller with more erect sides than other species described here. The surface is more ornate than *Diphuicrinus dovelyensis* but in summit view the appearance is striking similar. Additional material may clarify the status of this specimen.

Measurements of Figured Specimen in Millimeters

Width of cup—maximum	14.0
Width of cup—posteroanterior (est.)	12.5
Height of cup	4.9
Width of infrabasal circlet	2.0
Width and length of *AE* basal	4.4, 4.4*
Width of *CD* basal	4.8
Width of *B* radial	7.7
Length of *B* radial (to transverse ridge)	7.0*
Width and length of anal *X*	1.8, 3.9*
Diameter of proximal columnal	1.4

* measurements along surface curvature

Figured Specimen.—OU4754. Collected by Allen Graffham.

Occurrence.—Lester Limestone, Pennsylvanian (Desmoinesian); barrow pit on west side of road, Lake Murray State Park (SW ¼, NW ¼, sec. 9, T.6S., R.2E.), Love County, Oklahoma.

Genus ATOKACRINUS Knapp, 1969

Type-Species.—*Atokacrinus obscurus* Knapp, 1969, p. 358.

Diagnosis.—Basal concavity deep; infrabasals downflared; basals large; proximal tips of radials just above or in basal plane, articular facets horizontal; rudimentary anal plate near inner margin of cup. Arms and anal sac unknown. Stem small, round.

Discussion.—*Atokacrinus obscurus* Knapp is apparently a derivative of the lineage represented by typical *Palmerocrinus comptus* Knapp (1969, p. 361) which also has smooth plates. Evolution is through migration of the anal plate to a notch between radial articular facets toward the interior of the cup. The presently considered species from the Lester Limestone, *A. decorus* Strimple & Moore, n. sp., has an ornate surface typical of *Diphuicrinus*.

Occurrence.—Pennsylvanian (Atokan-Desmoinesian); USA (Oklahoma-Missouri).

ATOKACRINUS DECORUS Strimple & Moore, n. sp.
Figure 2,*1-3*

Description.—Dorsal cup low, wide, bowl-shaped, with broad basal concavity; infrabasals

1-3. Atokacrinus decorus Strimple & Moore, n. sp., basal, summit, and side *(CD)* views of holotype (OU6449), Lester Fm., Love Co., Okla., ×2.

4-6. Diphuicrinus pegmus Strimple & Moore, n. sp., side *(CD)*, summit, and basal views of holotype (OU6444), Frensley Fm., Carter Co., Okla., ×3.

7-10. D. dovelyensis Strimple & Moore, n. sp., *CD* interray, *A* ray, summit, basal views of paratype (OU6448), Lower Deese Fm., Carter Co., Okla., ×1.5.

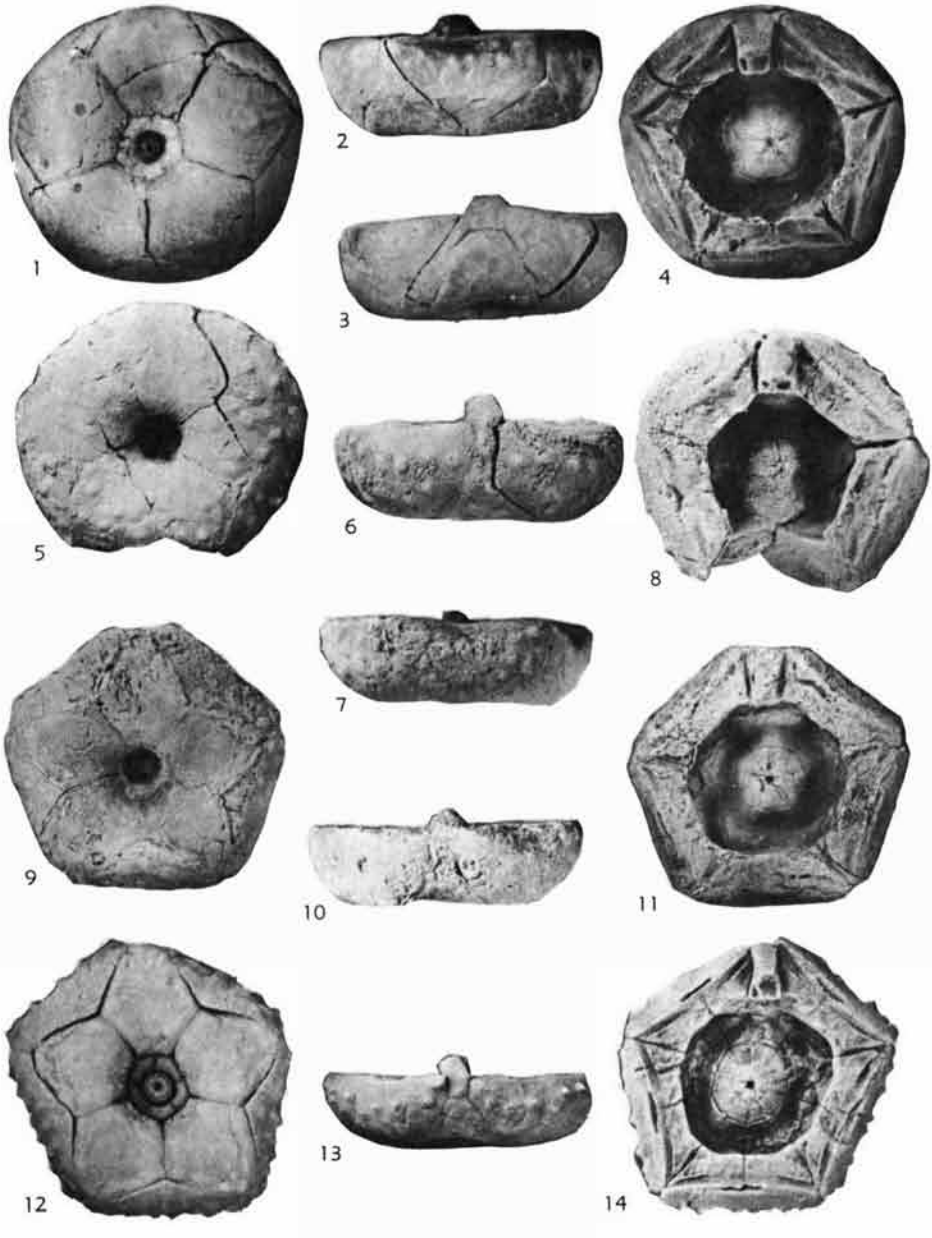

FIG. 3. Species of *Diphuicrinus* from Oklahoma.

1-4. Diphuicrinus dovelyensis STRIMPLE & MOORE, n. sp., holotype, basal, *A* ray, *CD* interray, summit views (OU6447), Dovely Ls., Savanna Fm., Rogers Co., Okla., ×1.8.

5-8. D. sp., basal, *CD* interray, *A* ray, summit of dorsal cup (OU4754), Lester Ls., Love Co., Okla., ×2.7.

9-11. D. coalensis (?) STRIMPLE & MOORE, n. sp., basal, *CD* interray, summit of hypotype (OU6446), Atokan? 100 feet above Gene Autry Shale, Johnson Co., Okla., ×1.8.

12-14. D. coalensis STRIMPLE & MOORE, n. sp., basal, *CD* interray, summit of holotype (OU6445), Atoka? Fm., Coal Co., Okla., ×1.8.

lost in preservation but circlet is relatively small; basals very large; distal tips of radials in basal plane but probably to an exaggerated degree due to compression of cup, articular facets horizontal, flattened forefacet present beyond outer ligament area; anal plate missing but opening is rather large, triangular when viewed from above, almost reaching exterior of cup.

DISCUSSION.—*Atokacrinus decorus* appears to be more closely related to *Diphuicrinus pegmus* STRIMPLE & MOORE, n. sp., than to *A. obscurus* KNAPP, 1969, type-species of the genus. The latter has more erect distal edges of radials and does not have an appreciable forefacet beyond the outer ligament area. Both *A. decorus* and *A. obscurus* have relatively large anal plates as compared to the anal plate of *Protencrinus* or *Erisocrinus*.

Measurement of Holotype in Millimeters

Width of cup posteroanterior and maximum	18.2, 20.0
Height of cup	6.0
Width of infrabasal circlet	3.2
Width and length of *AE* basal	8.0, 7.8*
Width of *CD* basal	8.0
Width of *B* radial	11.8
Length of *B* radial (to transverse ridge)	9.6*
Length of anal *X*	....
Width of anal *X* (notch)	1.9
Diameter of proximal columnal	2.1

* measurements along surface curvature

HOLOTYPE.—OU6449, Department of Geology, University of Oklahoma, Norman, Oklahoma. Collected by ALLEN GRAFFHAM.

OCCURRENCE.—Lester Limestone, Pennsylvanian (Desmoinesian?); SW ¼ NW ¼ NE ¼ sec. 9, T.6S., R.2E., Lake Murray State Park, Love County, Oklahoma.

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PART 2

PENNSYLVANIAN CRINOIDS FROM ALASKA

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ABSTRACT

Synbathocrinus alaskaensis STRIMPLE, ALLISON, & KLINE, n. sp. is found in association with *Eucatillocrinus richardsoni* STRIMPLE, ALLISON, & KLINE, n. sp., and *Coenocystis timmeri* STRIMPLE, ALLISON, & KLINE, n. sp., in Pennsylvanian (Atokan?) strata in the east-central Alaska Range, Alaska. *S. alaskaensis* is distinctive in possessing a bowl-shaped dorsal cup rather than the truncate cone-shaped cup typical of the genus.

INTRODUCTION

The fossil material discussed in this report comes from locality RM-8 in the northern Rainbow Mountain area, Alaska. Rainbow Mountain lies east of the Richardson Highway and south of Delta Junction and the Denali fault near 145° 40′ west longitude and 63° 20′ north latitude. Various field investigations during the last eight years in the vicinity of Rainbow Mountain have been carried out by students and staff members of the Department of Geology of the University of Alaska. ROWETT (1969) has reviewed the history of investigations in this area and documents the presence of both Pennsylvanian and Permian fossiliferous strata.

In 1962, LARRY G. HANSON collected several ammonoids (see HANSON, 1963) from the Rainbow Mountain Pennsylvanian sequence which were studied by UNKLESBAY and PAUKEN (1966). A paratype of *Pseudoparalegoceras hansoni* UNKLESBAY and PAUKEN, 1966 (UA-1023) comes from strata exposed at mile 212 on the Richardson Highway, the same sequence of beds which contain the crinoids discussed in this paper (locality RM-8). UNKLESBAY and PAUKEN refer these beds to the Early Pennsylvanian and call attention to the similarity of *P. hansoni* to *Pseudoparalegoceras* spp. known from the Atoka Formation of Oklahoma, the Magdalena Limestone of Texas, and the Bashkirian beds of the southern Ural Mountains of Russia.

ROWETT (1969, p. 14-15) has discussed the stratigraphy of the northern Rainbow Mountain area including a list of marine invertebrates and describing a new rugose coral, *Cryptophyllum striatum* ROWETT, 1969, from locality RM-8. He concluded that the fauna is Early Pennsylvanian in age (post-Morrowan, pre-Missourian).

GILBERTSON (1969, p. 29-31) in an unpublished Master of Science thesis from the University of Wisconsin gives a faunal list for the siliceous mudstone at mile 212 Richardson Highway in which two goniatites identified by GLENISTER and FURNISH are reported. These ammonoids are identified as *Proshumardites* sp. cf. *P. primus* PLUMMER & SCOTT, 1937, and gastrioceriin cf. *Syngastrioceras* sp. GLENISTER & FURNISH believe (*fide* GILBERTSON, op. cit.) that "the collection of goniatites and nautiloids from the mile 212 locality can 'best be fitted as Atokan Stage.'"

The brachiopod genera *Desmoinesia, Subansiria,* and *Tomiopsis* have been recognized by ROBERT L. GEBHARDT (personal communication, May, 1971) at RM-8 and appear to confirm a mid-Pennsylvanian age assignment for the crinoid-bearing stratum.

Fossil collections from RM-8 by HANSON, ROWETT, ALLISON and TIMMER, as well as by a number of students from invertebrate paleontology and summer field camp classes at the University of Alaska during the past two years, have resulted in many man-hours spent at the locality. While crinoid columnals are very abundant, only seven dorsal cups have been recovered to date. One dorsal cup was damaged by sectioning prior to its recognition as a crinoid, but fortunately another well-preserved specimen of this taxon has been found and identified as *Eucatillocrinus*. The rocks probably belong to the Atokan Stage of the Pennsylvanian System. All type material is in the repository, Department of Geology, The University of Iowa, Iowa City.

SYSTEMATIC DESCRIPTIONS

Order DISPARIDA Moore & Laudon, 1943

Family SYNBATHOCRINIDAE S. A. Miller, 1889

Genus SYNBATHOCRINUS Phillips, 1836

TYPE-SPECIES.—*Synbathocrinus conicus* PHILLIPS, 1836.

DIAGNOSIS.—Dorsal cup low, cone-shaped, base truncate; basals low, radials large, typically there is an oblique facet on the left shoulder of *C* radial for contact with single anal plate; arms five, composed of large quadrangular brachials; stem round.

DISCUSSION.—The range of *Synbathocrinus* has been restricted to pre-Pennsylvanian rocks by MOORE & EWERS (1942, p. 105) and by KESLING & SMITH (1963, p. 188).

The genus *Taidocrinus* TOLMATCHOFF (1924, 1931) was accepted for post-Mississippian symbathocrinids by the above-mentioned authors, MOORE & EWERS and KESLING & SMITH. As

noted by Strimple & Strimple (1968, p. 173) and previously by Moore & Ewers (*ibid.*, p. 105) the monotypic species *T. poljenowi* Tolmatchoff is damaged on one side, is poorly illustrated, and might be a typical *Synbathocrinus*. The supposed difference lies in whether a notch in the cup for anal *X* is present or absent. This cannot be verified from the illustrations since the Russian specimen is damaged and the criterion loses some significance in any event, since Van Sant (1964, fig. 26) has demonstrated variability in this characteristic. No notch is present for the anal *X* in the cup of some specimens of *S. swallovi* Hall from the Borden Limestone (Keokuk) of Indiana according to Van Sant. This may, however, be considered as *portentum*, a term suggested by Strimple (1963, p. 10, 11) for conditions abnormal to the forms in hand but of eventual evolutionary consequence. This concept is presented in another manner by Moore & Ewers (*ibid.*, p. 104-105) who state, "The fact that a very few specimens have an anal that slightly indents the summit of the radials does not serve to invalidate the concept of generic delimination of these very late Paleozoic forms from typical *Synbathocrinus* any more than the occasional absence of anal *X* from the cup of *Delocrinus* signifies lack of satisfactory clear definition of the latter genus." We certainly agree with the statement as it applies to the Permian forms from Timor described by Wanner, but it does not affect Pennsylvanian forms from North America.

A specimen ascribed to *S. melba* Strimple (1938) from the Burgner Formation (Atokan) of Missouri is figured by Burdick (1971) in which a distinct notch is found. Bassler & Moodey (1943, p. 696) accepted the generic assignment of *Synbathocrinus melba*. The taxon described here, *S. alaskaensis*, n. sp., from the Atokan? of Alaska, has a well-defined notch in the left shoulder of the *C radial* of two specimens, but has no notch in one specimen.

Occurrence.—Devonian to Pennsylvanian; North America, Europe.

SYNBATHOCRINUS ALASKAENSIS Strimple, Allison, & Kline, n. sp.

Figure 4,1-7,10

Description.—Dorsal cup bowl-shaped, height/width 0.5, surface irregularly granular, sutures deeply impressed. Basal circlet low, about 0.16 height of radials, composed of 3 plates, the smallest in *AE* interray. Basal plane horizontal with shallow impression for columnar attachment. Lateral sides erect, mildly curved. Radials large, convex surfaces, irregular dimensions, left shoulder of *C* radial lowered for reception of anal plate, proximal portions curved sharply into subhorizontal position, distal portions curved slightly inward, broad elongated facet area with long intermuscular notch, inner portions of facet flexed upward. Columnar scar depressed, large, round, perimeter marked by crenellae.

Measurements in Millimeters

	Paratype SUI34749	Holotype SUI35159
Width of cup (maximum)	12.7	11.7
Height of cup	6.5	5.7
Height of infrabasals	1.25	1.0
Width of radial, *A* ray—distal	6.8	3.1
—proximal	3.1	4.0
Width of radial, *B* ray—distal	6.1	6.4
—proximal	3.6	4.0
Width of radial, *C* ray—distal	7.8	6.9
—proximal	3.7	4.1
Width of radial, *D* ray—distal	7.2	6.5
—proximal	4.2	3.2
Width of radial, *E* ray—distal	6.7	6.6
—proximal	3.4	4.6

Discussion.—*Synbathocrinus alaskaensis*, n. sp., is distinctive in having a bowl-shaped dorsal cup rather than the truncate cone-shape typical of the genus. The basal circlet is sharply differentiated from the radial circlet, with distal portions partially obscured by the bulbous radial plates in side view of the cup. *S. melba* Strimple, 1938, is the only other related species of Pennsylvanian age and differs from *S. alaskaensis* in lacking pronounced bulbosity of radial plates. Moore (1941, p. 102-105) tentatively transferred *S. melba* to *Taidocrinus* Tolmatchoff (1924, 1931) which purportedly lacks an anal notch in the cup. Kesling & Smith (1963, p. 1187) endorsed this action and arbitrarily changed the name to *melbus*. The species was named for Melba L. Strimple and should retain the original spelling of *melba* as pointed out by Strimple & Strimple (1968, p. 172). The right shoulder of a radial plate (*D* radial) of a hypotype (SUI32233) of *S. melba* is depressed for contact with an anal plate as illustrated by

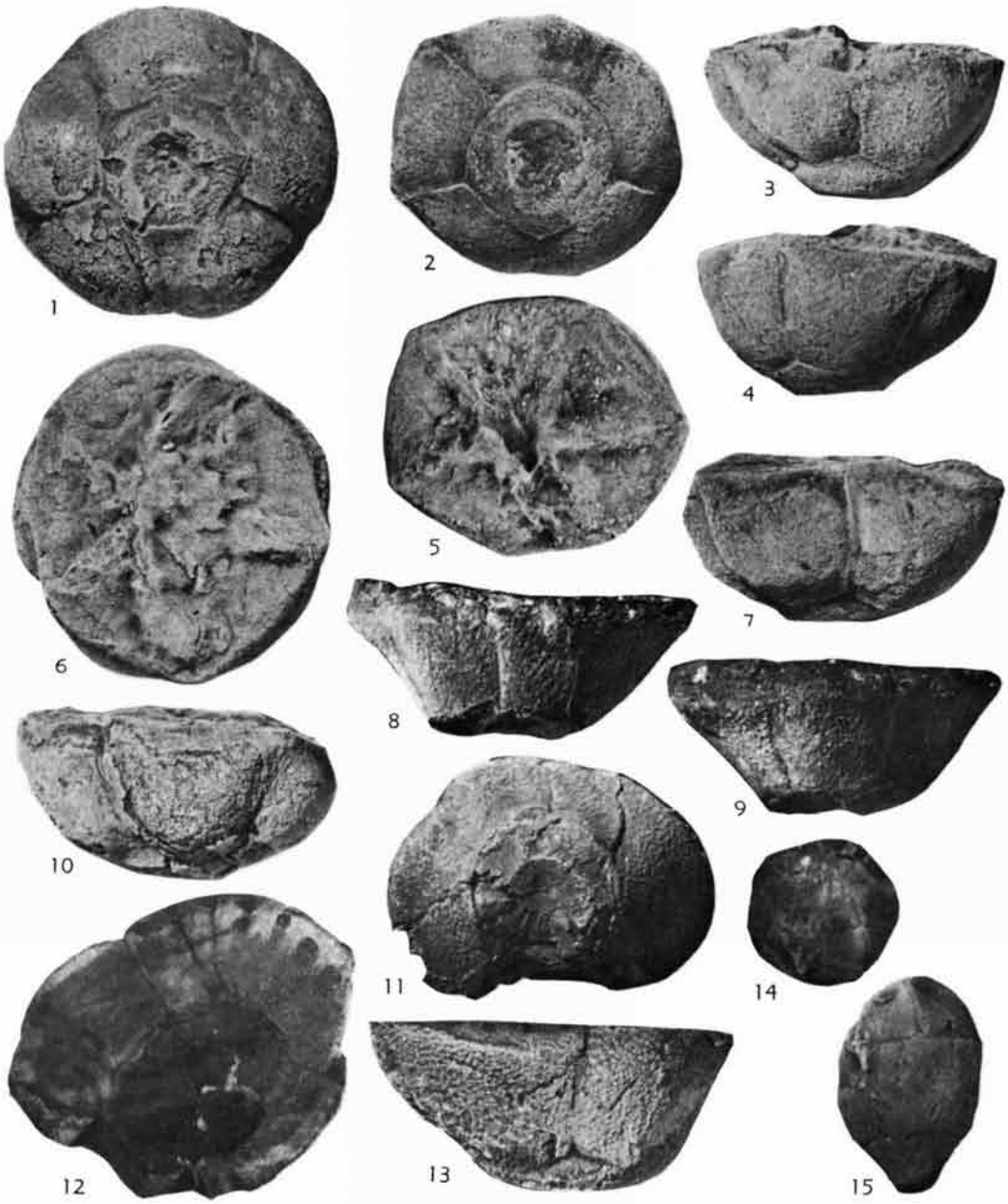

FIG. 4. *Synbathocrinus, Eucatillocrinus* and *Coenocystis* from Alaska.

1-7, 10. Synbathocrinus alaskaensis STRIMPLE, ALLISON, & KLINE, n. sp.; *1, 6-7, 10,* holotype viewed from base, summit, side view (*CD* interray); *2-5,* paratype viewed from base, summit, *CD* interray side view, anterior view?, *ca.* ×3.5.

8-9, 11-13. Eucatillocrinus richardsoni STRIMPLE, ALLISON, & KLINE, n. sp., *8-9, 11,* holotype viewed from *BC* side, anterior, and base; *12-13,* paratype viewed from summit and side, *ca.* ×3.5.

14-15. Coenocystis timmeri STRIMPLE, ALLISON, & KLINE, n. sp., holotype viewed from summit and side, *ca.* ×3.5.

STRIMPLE & STRIMPLE (*ibid.*, fig. 1A). In addition, there is an undescribed specimen of *Synbathocrinus melba* from the Burgner Formation (Atokan) of Missouri (USNM144997) showing a well-developed anal notch, which also verifies the presence of *Synbathocrinus* in the Pennsylvanian. The range of *Synbathocrinus* given by KESLING & SMITH (*ibid.*, p. 188) as "Devonian and Mississippian" must therefore be amended to include Pennsylvanian forms. The status of *Taidocrinus* is somewhat questionable in that the holotype of the type-species, *T. pojenowi*, is damaged in preservation and the presence or absence of an anal notch cannot be ascertained from the illustrations. Assuming the description to be correct, the genus *Taidocrinus* would include species from the Permian of Timor, originally described by WANNER (1916) as *Synbathocrinus campanulatus, S. campanulatus elongatus, S. campanulatus inflatus, S. constrictus,* and *S. constrictus sinuosus.*

TYPES.—Holotype catalogue no. SUI35159, paratypes catalogue no. SUI34693, SUI34749.

OCCURRENCE.—Atokan? strata at mile 212, Richardson Highway, Alaska.

Family ALLAGECRINIDAE Carpenter & Etheridge, 1881

Subfamily CATILLOCRININAE Moore, 1940

Genus EUCATILLOCRINUS Springer, 1923

TYPE-SPECIES.—*Catillocrinus bradleyi* MEEK & WORTHEN, 1868.

DIAGNOSIS.—Characters of the subfamily; distinguished by placement of anal plate which rests on left shoulder of *C* radial confluent with the normal distal edge of the cup.

DISCUSSION.—Other pre-Permian genera assigned to the Catillocrininae have a raised left shoulder of *C* radial (*Mycocrinus* SCHULTZ, 1865, *Catillocrinus* SHUMARD, 1866, *Metacatillocrinus* MOORE & STRIMPLE, 1942). *Paracatillocrinus* WANNER, 1916, has no articulation for a tube plate and has a low cup. *Eucatillocrinus* is a monotypic genus restricted to the Borden Formation (Keokuk) and it is with some reservation we assign a Pennsylvanian species to the genus (i.e., *Eucatillocrinus richardsoni*, n. sp.).

OCCURRENCE.—Mississippian (Keokuk)-Pennsylvanian (Atokan); North America (Indiana-Alaska).

EUCATILLOCRINUS RICHARDSONI Strimple, Allison, & Kline, n. sp.

Figures 4,*8-9,11-13*; 5,*2-3*

DESCRIPTION.—Cup relatively high, truncate cone-shaped. Basals form large, low disc, sutures obscured, columnar cicatrix rather small. *C* radial relatively small with 2 subhorizontal subequal facets, the left faceted for first plate of anal series; *B* radial has a single arm facet and is small; *A* and *D* radials are very wide and multifaceted for numerous arms; *E* radial is obscured in preservation.

DISCUSSION.—Two dorsal cups have been recovered, one of which unfortunately was sectioned before being identified as a crinoid. There is some similarity to *Allocatillocrinus* of Morrowan age, but the existence of 2 small radials (*B* and *C*) side by side aligns the species with the subfamily Catillocrininae rather than the Allagecrininae. The shape of the dorsal cup and nature of the facet for reception of the anal is closer to that of *Eucatillocrinus* than to other members of the subfamily.

E. bradleyi (MEEK & WORTHEN) from the Keokuk Limestone, Osagian Stage, Mississippian, is the only other species ascribed to the genus. The sides of the cup are slightly more erect than those of *E. richardsoni*. The Pennsylvanian species may eventually warrant separate generic status when details of the structure of the *E* radial and adjacent areas become known.

The specimen listed as "allagecrinid, cf. *Allocatillocrinus* sp." by GILBERTSON (1969, unpublished MS, p. 30) is possibly conspecific but has not been examined by us.

MEASUREMENTS IN MILLIMETERS.—Dorsal cup in longest axis, holotype 13.2 wide, paratype 15.5 wide; height of holotype 5.4, paratype 6.8.

TYPES.—Holotype catalogue no. SUI35160, paratype catalogue no. SUI34694.

OCCURRENCE.—Atokan? strata exposed at mile 212 on the Richardson Highway, Alaska.

Family HYPOCRINIDAE Jaekel, 1918

Genus COENOCYSTIS Girty, 1908

TYPE-SPECIES.—*Coenocystites richardsoni* GIRTY, 1908.

DIAGNOSIS.—Small, acornlike armless crinoids comprised of three circlets of plates. A round anal opening is located in the side at the juncture of three plates, between oral circlet and next

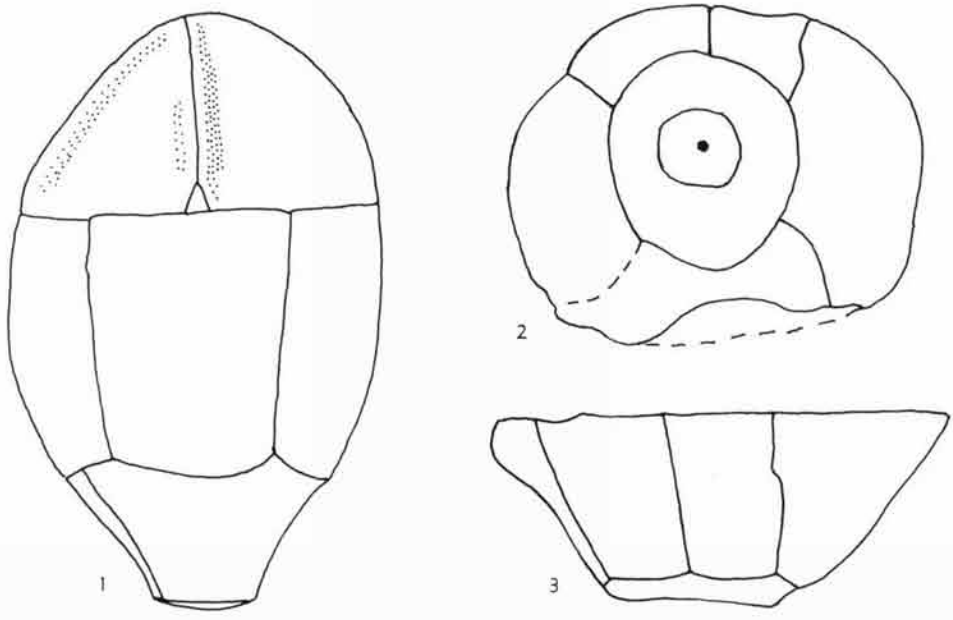

FIG. 5.—1. *Coenocystis timmeri* STRIMPLE, ALLISON, & KLINE, n. sp. Camera lucida drawings of holotype (SUI-34692) from side, ×7.0.——*2-3. Eucatillocrinus richardsoni* STRIMPLE, ALLISON, & KLINE, n. sp. Camera lucida drawings of holotype (SUI35160) viewed from base and *BC* rays.

circlet below. Lowermost circlet composed of fused plates, termed infrabasals by some authors but considered by us to be basals. The circlet flares upward from a round stem impression. The circlet above, considered here to be radials, consists of five plates and the next circlet consists of five orals which alternate with the radials.

DISCUSSION.—Several genera have been grouped together by WANNER, 1929, in the family Hypocrinidae and it has been demonstrated that some forms with a calyx similar to *Coenocystis* have in fact evolved from taxa having a fourth circlet of small radial plates. However, we are not satisfied that *Coenocystis* developed in this manner. PECK, 1936, ascribed a Mississippian form to *Coenocystis,* but STRIMPLE & KOENIG, 1956, placed the species *C. moreyi* in the genus *Kallimorphocrinus.*

OCCURRENCE.—Pennsylvanian (Atokan) to Lower Permian (Leonard-Word); North America.

COENOCYSTIS TIMMERI Strimple, Allison, & Kline, n. sp.

Figures 4,*14-15;* 5,*1*

DESCRIPTION.—The dorsal cup is small, pear-shaped, composed of 3 circlets of plates. Basals appear to be 3, 2 of subequal size and one small. Radials are 5 large elements lacking any development of arm articulating facets. Orals are 5, midportions concave and adsutural areas raised in the form of low ridges. Proximal ends of the orals do not meet at a central point, one is slightly longer than the rest (*CD?*) and two (*BC?* and *DE?*) are somewhat shorter. There does not appear to be any lateral opening in the side of the theca and a hydropore has not been observed.

DISCUSSION.—The configuration of the theca of *Coenocystis timmeri* is very similar to that of *Lageniocrinus seminulum* DE KONINCK (*fide* KIRK, 1940, fig. 7-12) even to the ridges on the orals; however, the orals are in direct series with the radials in that species, whereas, the orals alternate with the radials in the present form. The monotype of *Lageniocrinus seminulum* has a lateral opening in the side of the theca (*ibid.,* p. 130), but the opening is apparently not present in all specimens ascribed to the species.

Coenocystites timmeri could have evolved from Visean *Lageniocrinus* through rotation of the oral circlet to interradial position. The theca of *L. seminulum* is 6.4 mm high, approximately 4.5 mm wide. *Coenocystites timmeri* has a height of 8.3 mm, width 6.0 mm.

Coenocystis richardsoni (GIRTY) (1908, p.

108), from the Permian of Texas, has a similar calyx but with a pronounced anal opening in the side of the cup. GIRTY considered the radial plates to be missing and thus, described a lowermost fused circlet (infrabasals), 5 basals and 5 orals. We have preferred to call the lowermost circlet basals and the next circlet radials after KIRK (1940). The radials of *C. richardsoni* are proportionately shorter and the calyx much smaller than found in *C. timmeri*.

The relatively large size of the specimen at hand dispels any thought of it representing a larval or immature stage of some larger crinoid. KIRK (*ibid.*, p. 136-138) summarized the history of various authors' concepts of this group of fossils.

NAME.—The species is named for ROBERT S. TIMMER, who collected much of the material studied.

HOLOTYPE.—Catalogue no. SUI34692.

OCCURRENCE.—Atokan? strata exposed at mile 212, Richardson Highway, Alaska.

LOCALITY DESCRIPTION

RM-8. Number C. L. ROWETT (1969, p. 118). Blue-black siliceous and calcareous silty mudstone cut by dacite dike (1-2 feet thick). Locality on east side of Richardson Highway at base of steep bluff about 40 feet east of the highway and about 100 feet south of milepost 212 (mileposts numbered from Valdez). Locality about 4,200 feet stratigraphically above the base of the exposed section of the northern Rainbow Mountain area (*fide* ROWETT, 1969). Attitude approximately N 70° W, 70° SW, *not* overturned. Fossils come from the top of a 10-foot high talus cone of blue-black silty mudstone, and from the exposed surface of the fossil bed above it.

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PART 3

THE OCCURRENCE OF HYDRIOCRINUS IN OKLAHOMA AND RUSSIA

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ABSTRACT

Hydriocrinus turbinatus STRIMPLE, n. sp., is the youngest (Missourian) species from North America to be ascribed to *Hydriocrinus* TRAUTSCHOLD. The genus is typically Moscovian (lower Desmoinesian) from Russia and has been reported from the Desmoinesian of Texas.

INTRODUCTION

A small crown collected several years ago from the Wann Formation, Ochelata Group, Missourian, Pennsylvanian (Upper Carboniferous), just west of Bartlesville in Osage County, Oklahoma, is described herein as *Hydriocrinus turbinatus* STRIMPLE, n. sp., with discussion of the lineage leading from *Phacelocrinus* KIRK of Chesteran (Late Mississippian) age. An explanation of the pronounced change in the surfaces between anal plates in *CD* interray of the dorsal cup and proximal anal tube plates of *Hydriocrinus* is given (i.e., the development of articulation facets). In *Hydriocrinus* anal *X* and right tube plate have a common distal surface, not extended above the cup summit, and an outer ligament slit is present in each plate which is matched by a similar slit in the distal edge of the two proximal tube plates. In *Phacelocrinus* the upper surfaces of anal *X* and right tube plate are staggered, with latter extending well above anal *X*, and the distal surfaces are depressed in midportion.

The anal tube of *Hydriocrinus pusillus* TRAUTSCHOLD is illustrated (Fig. 6,*3*).

SYSTEMATIC DESCRIPTIONS

Order CLADIDA Moore & Laudon, 1943

Family SCYTALOCRINIDAE Moore & Laudon, 1943

Genus HYDRIOCRINUS Trautschold, 1867

TYPE-SPECIES.—*Hydriocrinus pusillus* TRAUTSCHOLD, 1867.

DIAGNOSIS.—Dorsal cup erect cone-shaped with infrabasals visible in side view; three anal plates, anal *X* and right tube plate have confluent distal surfaces and do not project above cup summit. Ten arms, long, slender, well-rounded exteriors, cuneiform brachials with a single pinnule on the long side, first primibrach elongate, axillary, constricted in midportion. Anal tube slender, comprised of irregular series of small polygonal plates. Column pentagonal.

DISCUSSION.—Although there is often a tendency in phyletic lineages for younger representatives to increase in size, after a maximum is attained there may be a reversal of the trend reflected by diminishment of size. *Phacelocrinus* KIRK (1940) attains a maximum size in the upper middle Chesteran. It is distinguished from homeomorphic or related forms in the possession of a large, pentagonal column. The oldest representative of the lineage of Pennsylvanian (Upper Carboniferous) age is *Hydriocrinus? rosei* MOORE & PLUMMER (1938) from the Bloyd Formation, Morrowan of Oklahoma, which retains a normal (primitive) arrangement of anal plates. The species was proposed based on a single specimen found in the Bloyd Formation (Morrowan), of Oklahoma, but a hypotype has

been reported by STRIMPLE (1961). In that the anal plates are in the same arrangement as found in Chesteran species, *H.? rosei* might be better ascribed to *Phacelocrinus*. The cup shape of *Hydriocrinus pusillus* TRAUTSCHOLD (1867) is almost identical with that of *Phacelocrinus* spp. from the Chesteran of Arkansas and Oklahoma and the arms are comparable. Difference lies in the posterior interradius wherein anal *X* and right tube plate form a confluent plane in *Hydriocrinus pusillus*. The latter species is from the Moscovian (Upper Carboniferous), zone C_2M, of Russia, which is considered here to correlate with the lower Desmoinesian, or possibly upper Atokan Stage of North America.

The confluent anal *X* and right tube plate have a development not found in these elements when they alternate in position (i.e., in normal or "primitive" arrangement), with the presence of an outer ligament pit furrow very similar to those found in the radial plates. The upper facets of anal *X* and right tube plate also slope inwardly, as do those of the radial facets, and appear to have weak muscle scars. It is therefore apparent that some movement of the anal tube toward the anterior of the animal is arranged. The anal tube of *H. pusillus* is shown herein by figure 6,*3*, a topotype (SUI33859) from near Moscow, Russia. It is postulated that the anal tube was directed toward the anterior while the animal was feeding and the arms were projected as a food-gathering fan toward the posterior into the current. Considering the rather delicate nature of the arms, there probably was a rather gentle current involved.

H. turbinatus STRIMPLE, n. sp., from the Wann Formation (Missourian) of northeastern Oklahoma, has a proportionately shorter cup than *H. pusillus*, with sides of cup more evenly expanded, and the column is in the process of changing from pentagonal to round (proximal columnal is subpentagonal, next is a nodal with circular outline and last preserved (an internodal) is subpentagonal).

Hydriocrinus lorraineae STRIMPLE & WATKINS, 1969, from the Millsap Lake Formation (Desmoinesian) of Parker and Hood Counties, Texas, has a long slender cup and subpentagonal proximal columnals very similar to *H. pusillus*. Unfortunately the anal plates are missing or somewhat disarranged in known specimens of *H. lorraineae* so that it is not possible to determine whether the anal plates are in typical arrangement for the genus.

Melbacrinus americanus STRIMPLE (1939), also from the Wann Formation (Missourian), has all characteristics of *Hydriocrinus turbinatus* except that the former has a round columnar cicatrix and the first primibrach is not axillary in every ray.

HYDRIOCRINUS TURBINATUS Strimple, n. sp.

Figure 6,*1-2*

Dorsal cup cone-shaped, evenly expanded, with 5 infrabasals rising directly from relatively large proximal columnals. Five basals are large

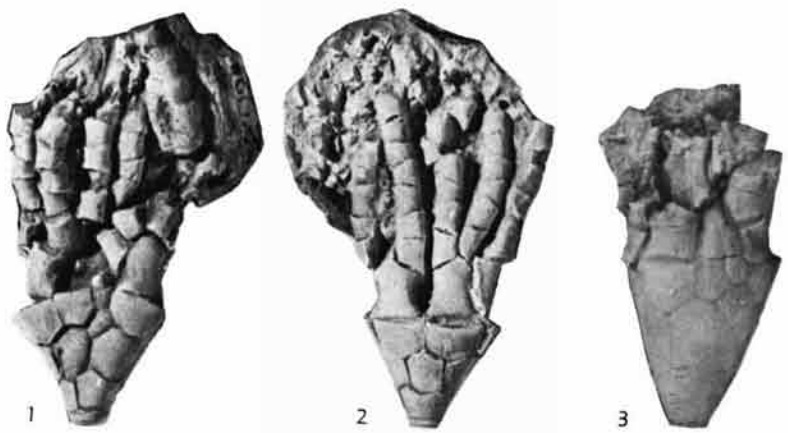

FIG. 6.——*1-2. Hydriocrinus turbinatus* STRIMPLE, n. sp., holotype viewed from posterior and anterior, ×1.7.——*3. H. pusillus* TRAUTSCHOLD, topotype (SUI33859) with anal tube exposed, viewed from posterior, ×1.7.

prominent elements. Five radials are wide with wide articular facets. The right posterior radial has a subhorizontal lower facet and contact with the right posterior basal. Three anal plates are in normal arrangement except for the upper surfaces of anal *X* and right tube plate which form a confluent plane and do not extend appreciably above the summit of the cup. This arrangement has been termed "Primitive Type B" in a study of plate arrangements within the posterior interradius by STRIMPLE (1960). Anal *X* is the largest plate of the three anals. All of the arm articular facets of the radial plate are not known but slight displacement of primibrachs reveal the presence of an unusually well-developed outer ligament furrow and a pronounced transverse ridge. Deep muscle scars are seen but oblique furrows seem to be absent. There is a slight notch between radials but essentially the primibrach fills the distal width of the radial. There are 10 arms. Primibrachs are axillary in all rays, slightly longer than wide, constricted in midportion and have a well-developed ridge between upper articulating surfaces. Secundibrachs have well-rounded exteriors and are alternatingly longer on one side with the long side bearing a pinnule.

Only 3 proximal columnals are preserved, the first being only partially developed and showing its slightly pentagonal nature in that only 5 tips are exposed. The second columnal is rounded, and is a nodal. The third columnal is an internodal and is pentagonal. The lumen is round.

Measurements of Holotype in Millimeters

Length of crown as preserved	29.5
Height of dorsal cup	7.3
Width of dorsal cup	10.1*
Height of infrabasal circlet	2.2
Width of infrabasal circlet	4.1*
Width and length of right anterior basal	3.1, 3.5
Width and length of right anterior radial	4.1, 3.0
Length of primibrach (average)	4.3
Width of primibrach at base	3.9
Width of proximal columnal	2.7

* slightly exaggerated by lateral compression

DISCUSSION.—There is a subtle distinction in the cup shape of *Hydriocrinus pusillus*, type-species, in that the sides of cup expand strongly for about a third of the cup height but thereafter there is only slight expansion. In *H. turbinatus* the sides of the cup expand evenly to the summit of the cup. The column of *H. pusillus* is decidedly pentagonal but in *H. turbinatus* the pentagonal shape is somewhat obscured.

The distinctive arrangement of anal plates in the posterior interradius termed Primitive Type B is found in both species. The anal *X* is proportionately larger in *Hydriocrinus turbinatus*. This same structure in the posterior interradius is found in *Melbacrinus americanus*; however, there is a decidedly rounded stem and the branching of the arms takes place on the second primibrach in some arms. *H. lorraineae* has a pentagonal stem and a long cup much like that of *H. pusillus*.

Hydriocrinus? rosei MOORE & PLUMMER (1938) from the Morrowan of Oklahoma has a pentagonal stem in proximal portion and has 3 anal plates in normal (primitive) arrangement. The arms are not known. Suggested assignment is to *Phacelocrinus*.

HOLOTYPE.—USNM no. 137780, collected by H. L. STRIMPLE.

OCCURRENCE.—Wann Formation, Ochelata Group, Pennsylvanian (Missourian); the mound on the west side of Mound Road, west of Bartlesville in the SE corner of sec. 3, T.26N., R.12E., Osage County, Oklahoma.

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PART 4

NOTES ON DELOCRINUS AND ENDELOCRINUS FROM THE LANE SHALE (MISSOURIAN) OF KANSAS CITY

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The University of Iowa, Iowa City; The University of Kansas, Lawrence

INTRODUCTION

Several specimens of *Delocrinus* and *Endelocrinus* collected from an exposure of the Lane Shale, Missourian Stage, Pennsylvanian, are discussed herein. The fossils were all obtained from the lowermost four feet of the formation south of the Kansas Turnpike at the southwest edge of Kansas City, Wyandotte County, Kansas.

Involved in the study is a dual element taking the place of a radial plate and an axillary primibrach *1*. The plate also serves to demonstrate the probable presence of specialized (ligamentous or muscular?) tissue between cup plates and therefore, invalidates the generally accepted concept that cup plates are joined by rigid sutures in all inadunates. Highly specialized spinose axillary primibrachs *1* are illustrated and one possible functional reason for their development is discussed. *Endelocrinus transitorius* STRIMPLE & MOORE, n. sp., is described and close affinity with *Delocrinus* is suggested.

A DUAL SKELETAL ELEMENT

An unusual plate of *Delocrinus subhemisphericus* MOORE & PLUMMER (=*D. hemisphericus*) illustrates the capability of a crinoid to generate almost any type of skeletal element needed to fulfill the basic requirements of the animal. The plate is a combination radial and primibrach *1*. Viewed from the exterior (Fig. 7,*1*) the plate has the general outline of a radial plate except for a blunt, spinelike protrusion in distal midsection. Viewed from the summit (Fig. 7,*2*) it is seen to be divided into two sections, for the reception of two secundibrachs *1*. Each articulating section is in the form of a triangle with a median ridge and outer denticulated areas. Large, well-defined muscle areas are present. A rather unique development is a projection housing two large and one small opening in midportion of the plate rather close to the inner edge. Comparable openings have never been observed by us among delocrinids and perhaps represent nerve canals which do not normally penetrate skeletal elements, although they are present in some Disparata. In the interior (Fig. 7,*3*) a long deep canal is present on each side of the plate. Less obvious canals are found occasionally on exceptionally well-preserved radial plates. The suture faces are also displayed by Figure 7,*3*, and various other suture faces of the plate by Figures 7,*4-7*. It is obvious that the suture faces are in fact depressed areas surrounded by a narrow, denticulated rim and occupied by a series of nodes and ridges. This feature is not restricted to the present specimen, but is, to some degree, fairly common among Pennsylvanian inadunates. It indicates the presence of special tissue, perhaps ligamental, holding cup plates together. This requires an amendment to the concept that cup plates of all inadunates are joined by rigid sutures. Several late Paleozoic lineages are known to have some muscular or ligamentous connective tissue, such as illustrated here.

ILLUSTRATED SPECIMEN.—SUI35236, Geology Department, The University of Iowa, Iowa City, collected by C. M. BAKER, Kansas City, Kansas.

OCCURRENCE.—Lane Shale, Upper Pennsylvanian (Missourian), Kansas City, Kansas.

SPINOSE PRIMIBRACHS OF DELOCRINUS

Numerous spinose axillary primibrachs *1* identified as *Delocrinus* sp. are present in the Lane Shale. Considerable variability is displayed and two examples are illustrated herein. The

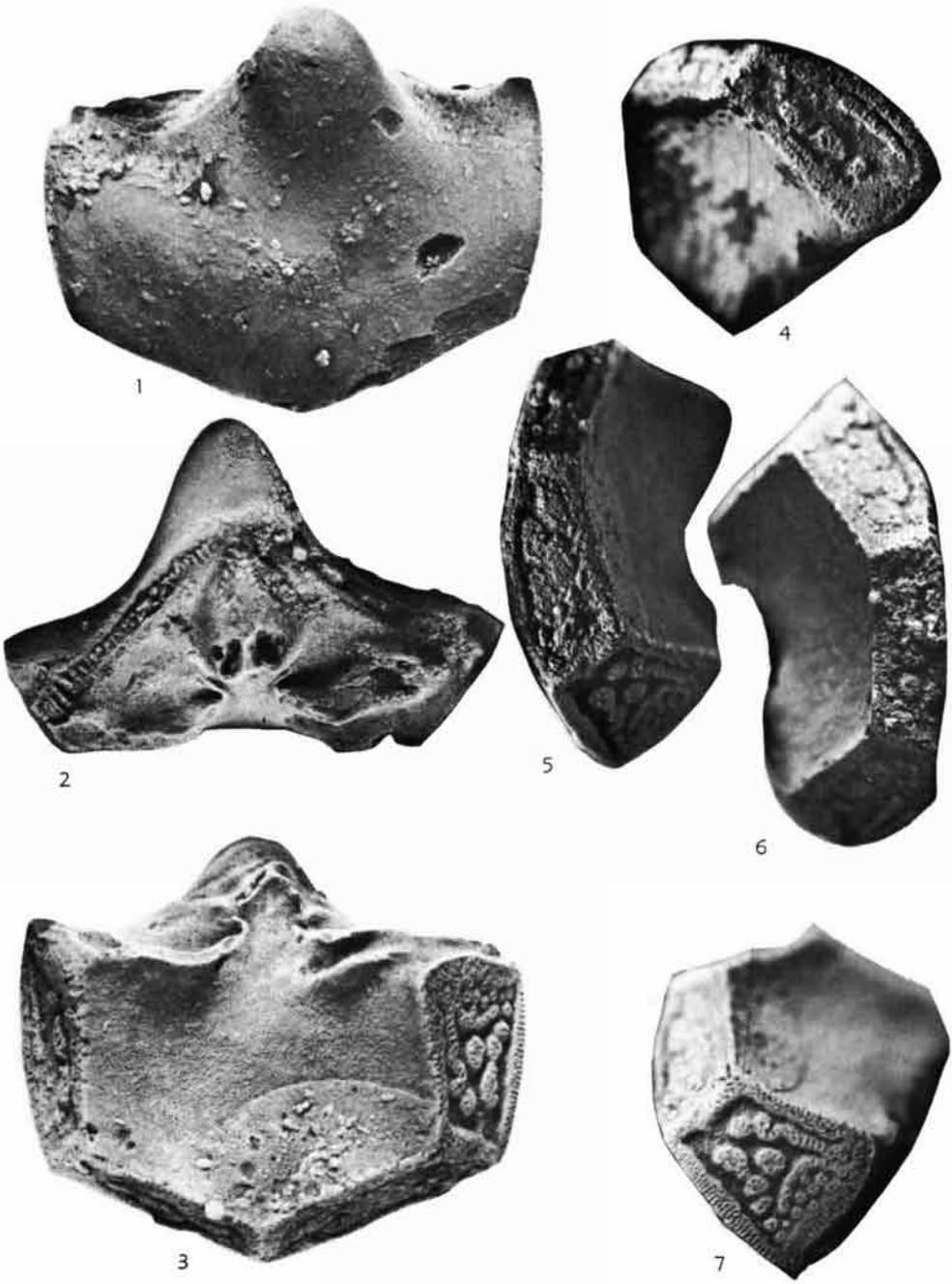

FIG. 7,*1-7*. *Delocrinus subhemisphericus* MOORE & PLUMMER from the Lane Shale (Upper Pennsylvanian) of Kansas City. A dual plate consisting of both a radial and primibrach *1* viewed from front, summit, interior, right lateral side, right proximal side, left proximal side, and left lateral side, ×6.5.

specimen (Fig. 8,*1-2*) is swollen near its termination and sharply fluted on distal sides with ridges more or less parallel to the long axis of the element. The posterior sides have a large, long groove in midportion of the bulbous extremity and are more or less flattened. Another specimen (Fig. 8,*3-4*) is unusually long and slender, with a slender pointed termination. The proximal side of the termination has a flattened surface. The proximal sides of spinose primibrachs of *Endelocrinus transitorius* are curved sharply upward into pointed ends but are rounded rather than flattened.

Any interpretation of the function of these morphological features is conjectural but we are inclined to believe many of these animals were often sitting on the sea bottom rather than always being well above the ocean floor and suspended by a column. The column is obviously relatively small and probably served more as a sea-anchor or tether than as a support. If resting directly on the floor of the sea, the spinose primibrachs could have acted as props to prevent the crown from being turned on its side by a strong current.

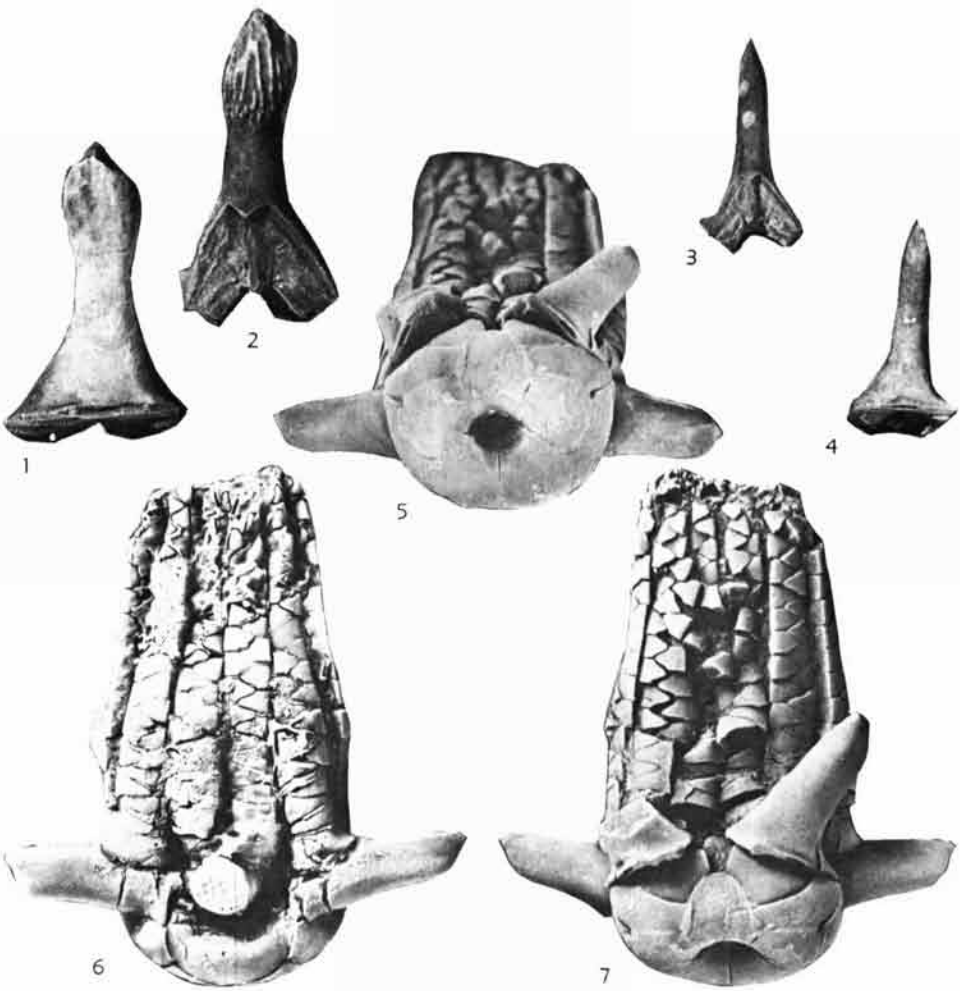

FIG. 8. *Delocrinus* and *Endelocrinus* from the Lane Shale (Upper Pennsylvanian) at Kansas City.

1-4. Delocrinus spp., spinose primibrach; *1-2*, proximal and distal views (SUI35241), ×2.5; *3-4*, proximal and distal views (SUI35242), ×1.3.

5-7. Endelocrinus transitorius STRIMPLE & MOORE, n. sp., holotype crown (SUI31877) basal view, view of *CD* interray, anterior views, ×2.5.

SYSTEMATIC DESCRIPTIONS

Family APOGRAPHIOCRINIDAE Moore & Laudon, 1943

Genus ENDELOCRINUS Moore & Plummer, 1940

Type-Species.—*Eupachycrinus fayettensis* Meek & Worthen, 1873.

Diagnosis (after Moore & Plummer, 1940, p. 296).—Under this name it is proposed to designate delocrinids with dorsal cups characterized by a strong transverse as well as longitudinal convexity of the basals and radials, which makes these plates appear distinctly bulbous; or by sharp inflections of the borders of the basals and radials at angle where they meet; or by both of these features. The arms are uniserial, composed of somewhat cuneate segments, in about the lower one-third of their length, becoming biserial above. Otherwise the characters appear to correspond exactly to those observed in *Delocrinus*.

Discussion.—There is evidence of small spinose extensions of the upper portions of axillary primibrachs *1* of the type species, *E. fayettensis*, although the projections have been broken off. Some species do not have projected primibrachs (e.g., *E. grafordensis* Moore & Plummer, 1940) and at least one has spinose primibrachs inseparable from *Delocrinus* (i.e., *Endelocrinus transitorius* Strimple & Moore, n. sp.). Strimple (1962) proposed the genus *Tholiacrinus* for endelocrinids having surface ornamentation. Knapp (1969) retained the generic name but modified the concept to include all endelocrinids having a pronounced basal concavity, strongly downflared infrabasals and having an outer ligament area (i.e., with radials curved inward distally). In that many intermediate forms are involved a more refined set of characteristics is required before this concept by Knapp could be applied.

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

ENDELOCRINUS TRANSITORIUS Strimple & Moore, n. sp.

Figure 8,5-7

Diagnosis.—Depressions at angles of cup plates; moderately wide, deep basal concavity; prominent, spinose axillary primibrachs *1*.

Discussion.—*Endelocrinus transitorius* demonstrates a relationship between *Endelocrinus* and *Delocrinus*. The arms of *E. transitorius* taper evenly distalward, whereas in typical *Delocrinus* there is a slight widening of the arms to about midlength and thereafter they taper. Contour of the dorsal cup of *E. transitorius* is almost identical with typical *Delocrinus* except for the dimplelike depressions at angles of the cup plates, which is a characteristic of *Endelocrinus*. The large, prominent axillary primibrachs *1* of *E. transitorius* are similar to those associated with typical *Delocrinus*, and serve to distinguish the species readily from other described forms of *Endelocrinus*.

Measurements of Holotype in Millimeters

Length of crown	28.5
Width of dorsal cup (maximum)	12.4
Height of dorsal cup	4.1
Width of infrabasal circlet (est.)	1.1
Width of *AB* basal	4.6
Length of *AB* basal	6.2*
Width of *CD* basal	4.6
Width of *B* radial	6.9
Length of *B* radial (to outer ligament area)	3.0*
Width of anal *X*	1.5
Length of anal *X*	?

* measurements along surface curvature.

Holotype.—SUI31877, Geology Department, The University of Iowa, Iowa City, Iowa. Collected by C. M. Baker, Kansas City, Kansas.

Occurrence.—Lane Shale, Upper Pennsylvanian (Missourian); Kansas City, Kansas.

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PART 5

A NEW MISSISSIPPIAN AMPELOCRINID

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INTRODUCTION

Two specimens collected by the Spencer Waters family of Moulton, Alabama, from a relatively new collecting site (WATERS & HOROWITZ, 1971) in Genevievian (Monteagle) rocks on Weatherly Mountain (SE ¼ sec. 5, T.5S., R.1E., Huntsville U.S. Geological Survey 7½ minute Quadrangle) south of Huntsville, Madison County, Alabama, provide the basis for description of *Armenocrinus watersi* STRIMPLE & HOROWITZ, n. gen., n. sp., and of more importance may provide a clue to the ancestry of the family Ampelocrinidae. Another specimen, collected several years ago by J. L. COLLINS from the Greenbrier Formation in the J. V. Thompson quarry, north of U.S. Hwy. 40, about 6.5 miles southeast of Uniontown, Wharton Township, Fayette County, Brownfield USGS 7½ minute Quadrangle, Pennsylvania, and is described as *Armenocrinus collinsi* STRIMPLE & HOROWITZ, n. sp. *Barycrinus neglectus* MILLER & GURLEY from the Borden Formation (Keokuk), Crawfordsville, Montgomery County, Indiana, is considered to be congeneric.

SYSTEMATIC DESCRIPTIONS

Family AMPELOCRINIDAE Kirk, 1942

DIAGNOSIS.—Crown expanded; dorsal cup low or high cone-shaped, infrabasals visible in side view; single anal plate in cup (radianal); primibrachs two to four; arms may subsequently bifurcate, uniserial, brachials with rounded exteriors, syzygial pairs common; anal sac recurved or straight; stem subpentagonal, may become rounded very near cup.

SUBFAMILIES.—*Ampelocrininae* KIRK, 1942; *Paragassizocrininae* STRIMPLE & WATKINS, 1969.

DISCUSSION.—The family Ampelocrinidae, as presently defined, includes forms with many divergent morphologic characters such as atrophied stems (e.g., *Paragassizocrinus*) versus subpentagonal (e.g., *Ampelocrinus*), pentastellate (e.g., *Chlidonocrinus*) or round stems (e.g., *Armenocrinus*). It is beyond the scope of the present paper to attempt further refinement of the family or its subfamilies other than to point out its homologous nature.

OCCURRENCE.—Mississippian (Osagian-Chesteran)-Permian; USA, Europe, USSR.

Subfamily AMPELOCRININAE Kirk, 1942

DIAGNOSIS.—The Ampelocrininae are differentiated from the Paragassizocrininae in that the infrabasals of the latter group have a tendency toward fusion and the stem is atrophied.

GENERA.—*Ampelocrinus* KIRK, 1942; *Polusocrinus* STRIMPLE, 1951; *Moundocrinus* STRIMPLE, 1939; *Chlidonocrinus* STRIMPLE & WATKINS, 1969; *Halogetocrinus* STRIMPLE & MOORE, 1971; *Armenocrinus* STRIMPLE & HOROWITZ, n. gen.

OCCURRENCE.—Mississippian (Osagian-Chesteran)-Permian; USA, Europe, USSR.

Genus ARMENOCRINUS Strimple & Horowitz, n. gen.

TYPE-SPECIES.—*Armenocrinus watersi* STRIMPLE & HOROWITZ, n. sp.

DIAGNOSIS.—Dorsal cup and infrabasals more erect than typical for other Mississippian members of the subfamily and primibrachs more numerous. *Armenocrinus* has arms which branch on primibrachs *2-4* but in all other genera on primibrach *2*.

SPECIES.—*Armenocrinus watersi* STRIMPLE & HOROWITZ, n. sp., *Armenocrinus collinsi* STRIMPLE & HOROWITZ, n. sp., *Barycrinus neglectus* MILLER & GURLEY.

DISCUSSION.—*Barycrinus neglectus* MILLER & GURLEY, 1896, from the Borden Formation

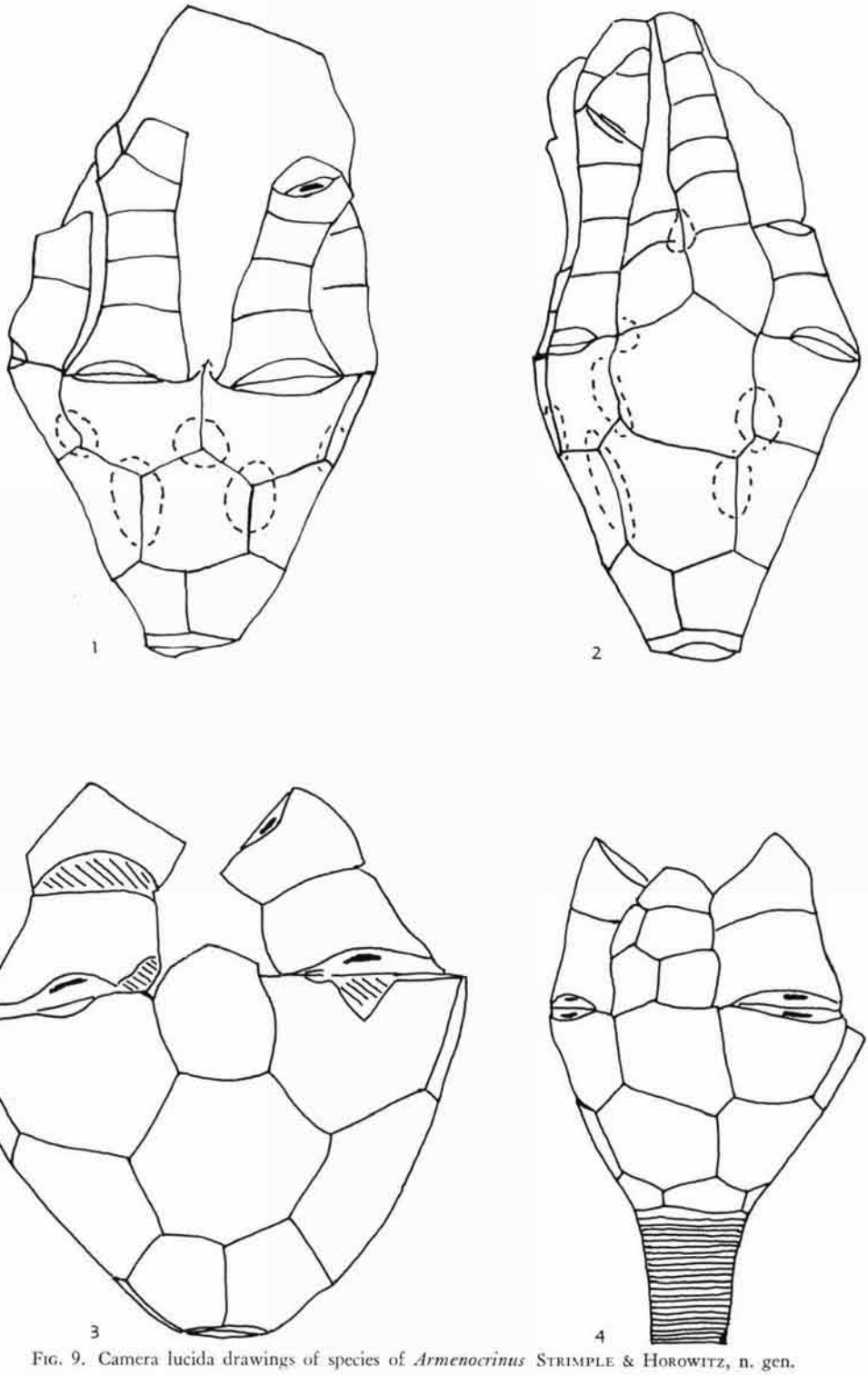

FIG. 9. Camera lucida drawings of species of *Armenocrinus* STRIMPLE & HOROWITZ, n. gen.

(Continued on facing page.)

(Keokuk) near Crawfordsville, Indiana, is in the direct lineage. Characteristics in common with the type-species of *Armenocrinus* are 1) granular surfaces, 2) multiple primibrachs, 3) gaped suture between radial and primibrach 1, 4) single anal plate, 5) high cone-shaped cup. Van Sant in Van Sant & Lane (1964, p. 77) noted, "The peculiar structure of the *CD* interray and gaped sutures are unknown in other forms assigned to this genus (*sic, Barycrinus*) and it is possible that this species should be assigned to a new genus." Assignment is made here to *Armenocrinus neglectus* (Miller & Gurley), n. comb.

The primary lineage represented by *A. neglectus* and *A. watersi* continues into the Pennsylvanian where it is apparently represented by *Halogetocrinus* Strimple & Moore, 1971. The cup of *Halogetocrinus* is smaller and considerably lower, with infrabasals subhorizontal in attitude, all of which is to be expected in normal evolution. The single anal plate has widened somewhat but is still followed by two tube plates above, and has retained a diagonal contact with *CD* basal and a short facet in contact with *BC* basal. Structure of the arms has changed somewhat in *Halogetocrinus* in that only five primary arms are developed and an armlet or two may occur in the lower portions of the arms.

Ancestry of *Armenocrinus* probably lies in *Culmicrinus,* specifically with a form like *C. thomasi* Laudon (1933) from the Gilmore City Formation (upper Kinderhookian). *C. thomasi* is atypical of the genus *Culmicrinus* in that some arms have fewer primibrachs than found in younger species of the genus, also in having subpentagonal proximal columnals (previously unreported).

Occurrence.—Mississippian (Osagian-Genevievian); USA (Indiana-Pennsylvania-Alabama).

ARMENOCRINUS WATERSI Strimple & Horowitz, n. sp.

Figures 9,*4*; 10,*1,4*

Diagnosis.—Relatively large, erect cone-shaped cup, primibrach 2 axillary in all except *A* ray where primibrach 3 is axillary.

Discussion.—*Armenocrinus watersi* is a relatively large species and is unusual in having a rapidly tapering stem with the large most proximal segment pentagonal, all other columnals rounded. The large anal plate (radianal) extends slightly above the cup summit, rests diagonally on *CD* basal and has a short facet in contact with *BC* basal. The entire surface is covered by minute closely spaced granules.

Measurements of Holotype in Millimeters

Maximum width of cup	10.8
Minimum width of cup (postero-anterior)	10.0
Height of cup	6.7
Width and height of infrabasal circlet	5.3, 1.5
Width and length of *DE* basal	4.0, 3.8
Width and length of *A* radial	5.6, 3.1
Width of anal plate (radianal)	3.5
Length of radianal	3.2
Diameter proximal columnal	4.0

Types.—Holotype IU10837-17; paratype IU10837-18.

Occurrence.—St. Genevieve interval displaced, but probably from interval 95 to 100 feet below the Huntsville-Monteagle contact (Waters & Horowitz, 1971), Monteagle Limestone, Mississippian (Gasperian); Weatherly Mountain, Huntsville, Alabama.

ARMENOCRINUS COLLINSI Strimple & Horowitz, n. sp.

Figures 9,*3*; 10,*2-3,5*

Diagnosis.—Relatively robust, erect cone-shaped dorsal cup, primibrach 2 axillary in all rays.

Discussion.—*A. collinsi* is a larger form than *A. watersi*. It differs from *A. watersi* in having much smaller proximal columnals, 2 of which are preserved and are subpentagonal. The proximal facet of radianal is horizontal and is well removed from *BC* basal, the infrabasals are much larger and proportionately longer.

Measurements of Holotype in Millimeters

Maximum width of cup	16.9
Minimum (anteroposterior)	13.4
Height of cup	10.2
Width and height of infrabasal circlet	7.3, 2.8
Width and length of *DE* basal	7.0, 6.4
Width and length of *A* radial	9.0, 5.0

1-2. A. neglectus (Miller & Gurley), holotype viewed from *A* ray and *CD* interray, depressed areas outlined, ×4.5.

3. A. collinsi Strimple & Horowitz, n. sp., holotype viewed from *CD* interray, ×4.5.

4. A. watersi Strimple & Horowitz, n. sp., holotype viewed from *CD* interray, ×4.5.

FIG. 10.——*1,4. Armenocrinus watersi* STRIMPLE & HOROWITZ, n. sp., holotype (IU10837-17) viewed from *CD* interray and *A* ray, ×2.3.——*2-3,5. A. collinsi* STRIMPLE & HOROWITZ, n. sp., holotype (SUI35167) viewed from *CD* interray, *A* ray, and base, ×3.

Width and length of anal plate	4.0, 4.6
Diameter proximal columnal	1.9

HOLOTYPE.—SUI35167, Geology Department, The University of Iowa, Iowa City. Collected by J. L. COLLINS.

OCCURRENCE.—Greenbrier Formation, Mississippian (probably Chesteran); J. V. Thompson abandoned quarry, Brownfield U.S. Geol. Survey 7½-minute Quadrangle, north of U.S. Highway 40, 6½ miles southwest of Uniontown, Wharton Township, Fayette County, Pennsylvania.

ARMENOCRINUS NEGLECTUS (Miller & Gurley), 1896, n. comb.

Figure 9,*1-2*

DIAGNOSIS.—Longitudinal depressions between radials, small, rounded, deep pits at angles between basals and radials; radial facets gaping; first arm branching with primibrach *4*.

DISCUSSION.—*A. neglectus* compares more favorably with *A. watersi* than with *A. collinsi* but differs from both species in having more pronounced depressions. STRIMPLE has examined the holotype and found the sutures and depressions have been outlined with black ink, more or less consistent with their actual placement and shape. The areas are sharply depressed. Camera lucida drawings are provided (Fig. 9) to illustrate the actual sutures. Infrabasals are slightly shorter than illustrated by VAN SANT (1964, pl. 1, fig. 10, 12). Actually, there are plications extending between cup plates with intervening areas depressed. A remnant of the structure is found in *A. watersi,* manifested as small depressions at the angles of radial and basal plates.

HOLOTYPE.—Catalogue no. 6489, Field Museum of Natural History, Chicago, Illinois.

OCCURRENCE.—Borden Formation (Keokuk), Mississippian (Osagian); Crawfordsville, Montgomery County, Indiana.

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PART 6

NOTES ON STENOPECRINUS AND PERIMESTOCRINUS

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ABSTRACT

Two spectacular specimens of *Perimestocrinus ibexensis* STRIMPLE & BOARDMAN, n. sp., from the Ibex Formation of North Central, Texas, are discussed in detail. A photographic illustration of *P. noduliferus,* type of the genus, is included for comparative purposes. *Stenopecrinus hexagonarius* is reported for the first time from the LaSalle Limestone Member, Bond Formation (Missourian), of Illinois to illustrate the nature of the anal sac and for comparison with *Perimestocrinus.*

INTRODUCTION

A closer relationship between *Perimestocrinus* MOORE & PLUMMER (1938) and *Stenopecrinus* STRIMPLE (1961) than with most genera of the Pirasocrinidae is ascribed to common features of their relatively deep dorsal cup with erect sides and pronounced basal concavity. Basal plates flex sharply into the basal invagination and form vertical or even overhanging side walls. *Triceracrinus* BRAMLETT (1943) appears to be a somewhat specialized derivative of *Perimestocrinus,* with basals projected downward.

A new illustration of the holotype *Perimestocrinus noduliferus* (MILLER & GURLEY), type-species of *Perimestocrinus,* is given (Fig. 12,3) for comparative purposes.

Stenopecrinus hexagonarius STRIMPLE (1952) is reported for the first time from the LaSalle Limestone, Bond Formation (Missourian), near Pontiac, Illinois. An anal tube in excellent preservation is illustrated (Fig. 12,2).

Two specimens from the Ibex Formation, Lower Permian, of north-central Texas are described as *Perimestocrinus ibexensis,* n. sp. The anal tube of *P. ibexensis* is composed of six series of plates, as in *Stenopecrinus hexagonarius,* but are more rugose and strongly keeled. It is worthy of note that the anal plates of the *CD* interray are rather consistently stable in position in *Perimestocrinus* as presently defined, whereas in *Stenopecrinus* there is a tendency toward elimination of some anal elements from the cup.

SYSTEMATIC DESCRIPTIONS

Suborder DENDROCRINOIDEA Bather, 1899

Family PIRASOCRINIDAE Moore & Laudon, 1943

Genus PERIMESTOCRINUS Moore & Plummer, 1938

TYPE-SPECIES.—*Hydreionocrinus noduliferus* MILLER & GURLEY, 1894.

DIAGNOSIS.—Dorsal cup low, bowl-shaped, base decidedly concave; three anal plates in cup; axillary primibrach *1* elongate, marked by three or four nodes in proximal region and a single node in distal area, subsequent brachials uniserial, each marked by a node on alternate sides. Column round.

DISCUSSION.—Comparison with *Stenopecrinus* has been made under that genus. An illustration of the holotype of the type-species, *P. noduliferus,* is given by Figure 12,*3*.

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

PERIMESTOCRINUS IBEXENSIS Strimple & Boardman, n. sp.

Figures 11,*1-2*; 12,*4-7*

DIAGNOSIS.—Surface of cup undulating, covered by small pustules and granulations, sutures deeply incised; arms mildly keeled, granulose, bear 2 nodes on each brachial; anal tube composed of series of 6 plates, each series prominently keeled.

DESCRIPTION.—In addition to features discussed above, the cup is moderately low, basals large and prominent, 3 anal plates in normal (primitive) arrangement; axillary primibrach *1* has a horizontal series of small nodes in proximal region and is protruded with a series of small nodes in distal region; endotomous branching of arms at irregular heights. Anal tube plates have 2 respiratory slits on each side and proximal ends rest on distal inner edge of radials except in *CD* interray. Stem is round.

DISCUSSION.—*Perimestocrinus ibexensis* has some features comparable to those of *Triceracrinus moorei* BRAMLETTE, 1943; however, the latter species has nodose or projecting basals not found in the former; *T. moorei* was assigned to *Utharocrinus* MOORE & PLUMMER by STRIMPLE, 1950, and subsequently, with restriction of *Utharocrinus* to the type-species, *U. pentanodus,* it was ascribed to *Perimestocrinus*. It now appears that *Triceracrinus* is a valid Upper Pennsylvanian (Virgilian) and Lower Permian genus, based on the downward-projecting basals.

Perimestocrinus granulosus (STRIMPLE), 1939, is closely comparable to *P. ibexensis* but differs in having slightly flared radials and more evenly curved cup plates.

Measurements of Perimestocrinus ibexensis

	Holotype	Paratype
Length of arms (as preserved)	....	34.0
Width of cup (maximum)	16.7	13.3
Height of cup	5.8	5.7
Length of basal	7.8*	6.8*
Width of basal	6.0	4.9

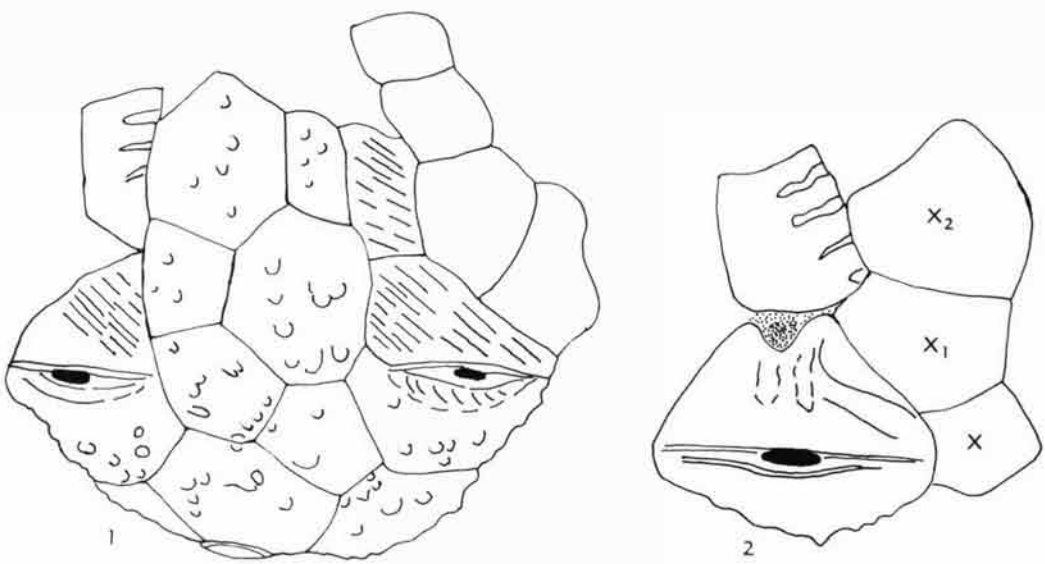

FIG. 11. *Perimestocrinus ibexensis* STRIMPLE & BOARDMAN, n. sp. Camera lucida drawing of holotype (SUI35239). ——*1*. View of *CD* interray, ×4.5.——2. Oblique view showing steep, elongated articular facet of *D* radial and proximal anal tube plate resting on distal edge, ×4.5.

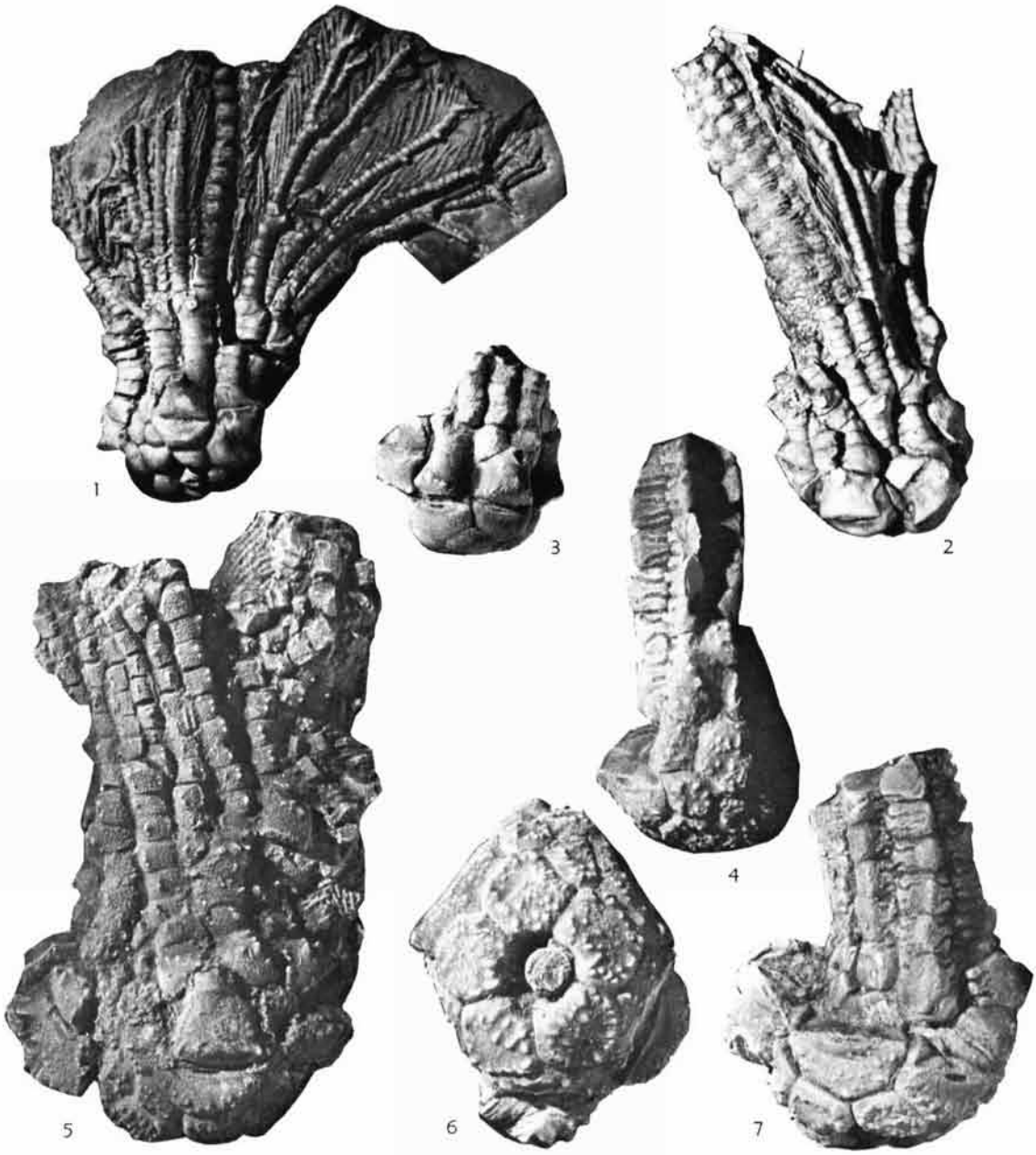

FIG. 12. *Stenopecrinus* from LaSalle Limestone, Illinois, and *Perimestocrinus* from Missouri and Texas.

1-2. Stenopecrinus hexagonarius (STRIMPLE). Hypotype crown from LaSalle Limestone, Livingston Co., Ill.; *1, CD* interray to left; *2,* AE interray view with portion of arms removed showing the anal tube to left. Terminating platform missing, ×1.25.

3. Perimestocrinus nodulifer (MILLER & GURLEY). Holotype crown from Missourian stage, Jackson Co., Mo., viewed from anterior, ×1.5.

4-7. Perimestocrinus ibexensis STRIMPLE & BOARDMAN, n. sp. from Ibex Formation, Eastland Co., Texas; *4, 6, 7,* holotype from *CD* interray showing rugose anal tube, base, and *A* ray; *5,* paratype from *D* ray showing arm structure, all ×3.

Length of radial (to transverse ridge)	4.6*	5.6*
Width of radial	8.7	8.0
Diameter of proximal columnals	3.0	2.9

* measurements along surface curvature

TYPES.—Holotype SUI35239, paratype SUI35240, collected by DARWIN BOARDMAN II.

OCCURRENCE.—Watts Creek Shale Member, Ibex Fm., Lower Permian; 3 miles north of Lake Cisco Dam in roadcut along Cisco-Moran road, Eastland County, Texas.

Genus STENOPECRINUS Strimple, 1961

TYPE-SPECIES.—*Stenopecrinus planus* STRIMPLE, 1952.

DIAGNOSIS.—Dorsal cup low, bowl-shaped with rather deep, narrow basal concavity. Proximal portions of basals form sides of basal cavity and curve outward to form broad basal plane and upward to be visible in side view of cup. Articular facets slope gently outward, do not quite fill distal face of radials. Three anal plates in cup, normal to advanced arrangement. Arms uniserial, endotomous branching, rounded exteriors. Axillary primibrach *1* extended as small spine in distal portion and subsequent axillaries are spinose. Anal sac tall, cylindrical, composed of series of six plates, respiratory canals along lateral sides of sac plates, small umbrellalike termination above arms composed of about six polygonal plates surrounded by about seven large, spinose plates. Stem round.

DISCUSSION.—*Stenopecrinus* is distinguished from *Plaxocrinus* MOORE & PLUMMER by having a deeper cup and a more pronounced basal concavity. In *Plaxocrinus* axillary primibrach *1* has a proportionately low, and larger spinose extension. Subsequent axillaries are not produced as spines. *Perimestocrinus* MOORE & PLUMMER has a cup similar to that of *Stenopecrinus* but none of the axillaries are spinose. The termination of the anal tube of *Perimestocrinus* is known to be spinose but its exact structure is not clear.

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

STENOPECRINUS HEXAGONARIUS Strimple, 1952

Figures 12,*1-2*

DIAGNOSIS.—Dorsal cup low, broad, ornamented by fine but distinct granules, sutures impressed, pronounced basal concavity, crown very tall.

DISCUSSION.—*Stenopecrinus hexagonarius* may be distinguished from *S. planus* in having a lower cup and more incised sutures. The anal tube plates of *S. hexagonarius* have 4 respiratory slits to a side, whereas those of *S. planus* have only 2 slits. The crown of *S. hexagonarius* is somewhat longer than that of *S. planus*.

HYPOTYPE.—IGS42P173, collected by CHRISTINA CLEBURN.

OCCURRENCE.—LaSalle Limestone, Bond Formation, Pennsylvanian (Missourian); Wagner Stone Company Quarry, south of Pontiac, Livingston County, Illinois.

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———, 1961, *Late Desmoinesian crinoid faunule from Oklahoma:* Oklahoma Geol. Survey Bull. 93, 189 p., 19 pl.

PART 7

AGNOSTOCRINUS FROM THE UPPER PERMIAN OF TEXAS

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ABSTRACT

The genus *Agnostocrinus* WEBSTER & LANE, 1967, is typically from the Lower Permian of Nevada. A form here described as *Agnostocrinus ornatus* STRIMPLE, n. sp., is from the Upper Permian of Texas.

INTRODUCTION

STRIMPLE (1966, p. 80) reported the first indocrinid from North America as *Metaindocrinus cooperi* STRIMPLE. The specimen was obtained by dissolving a block of limestone in 10 percent hydrochloric acid from a locality about two miles northeast of the junction of Hess Canyon with the south branch of Hess Canyon, Hess Canyon quadrangle, Texas. The horizon is the upper part of the Word Formation (between limestones no. 3 and no. 4). Relationship with *Indocrinus* WANNER and *Proindocrinus* YAKOVLEV from the Permian of Timor, Indonesia, and the Ural Mountains, Russia, was discussed. Another form recovered from the same block of limestone is described here as *Agnostocrinus ornatus* STRIMPLE, n. sp. The only other species ascribed to the genus is *A. typus* WEBSTER & LANE, 1967, from the Lower Permian of Nevada.

SYSTEMATIC DESCRIPTIONS

Order CLADIDA Moore & Laudon, 1943

Suborder POTERIOCRINITINA Jaekel, 1918

Family BLOTHROCRINIDAE Moore & Laudon, 1943

Genus AGNOSTOCRINUS Webster & Lane, 1967

TYPE-SPECIES.—*Agnostocrinus typus* WEBSTER & LANE, 1967.

DIAGNOSIS (after WEBSTER & LANE).—Cup bowl-shaped, with basal concavity; one anal plate; arms uniserial, branching on first primibrach in all rays and on first secundibrach in *A, C,* and *D* rays only; anal tube long, cylindrical, narrow.

DISCUSSION.—*Agnostocrinus typus* is reported to have the single anal plate followed by two tube plates above the summit of the cup which distinguishes the genus, on the basis of cup morphology, from most Pennsylvanian-Permian genera having a single anal plate. *Apographiocrinus* has a comparable cup and anal plate but differs in having long projections of the outer cup surface extending between radial articular facets. There is considerable difference in arm structure in that *Apographiocrinus* has ten closely fitted arms, with almost flattened exteriors, whereas *Agnostocrinus* has more than ten arms which have well-rounded exteriors. *Contocrinus* KNAPP has arms similar to *Apographiocrinus,* but the anal plate is followed by a single tube plate.

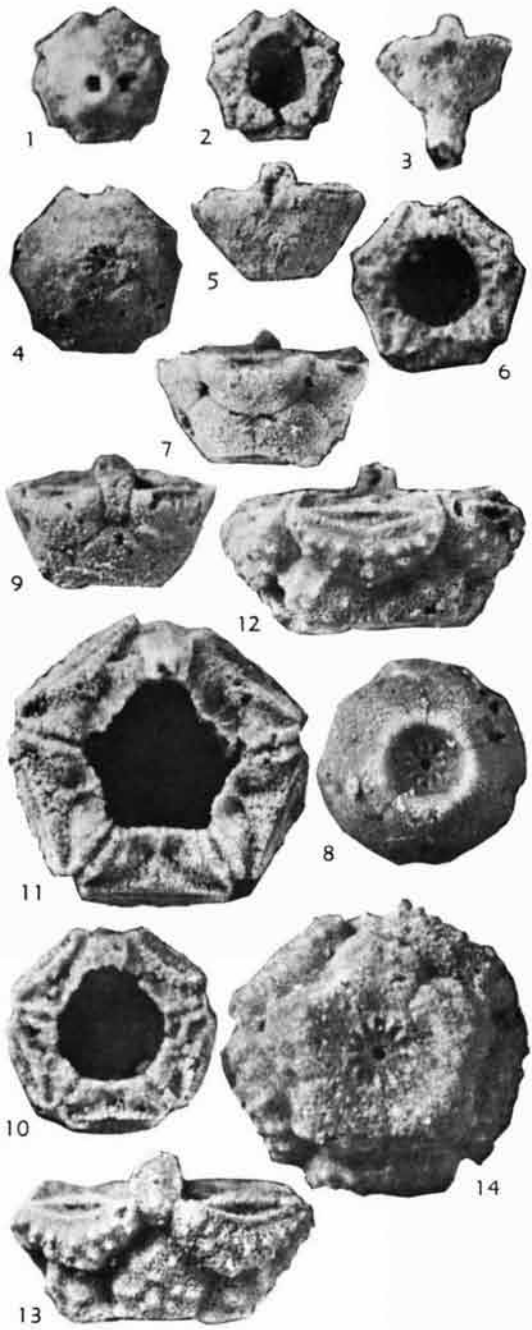
OCCURRENCE.—Lower and Upper Permian; USA (Nevada-Texas).

AGNOSTOCRINUS ORNATUS Strimple, n. sp.

Figure 13,*1-14*

DIAGNOSIS.—Characters of genus except that arms are not preserved in presently considered species.

DISCUSSION.—A young specimen of *A. ornatus* (Fig. 13,*1-3*) has a rather long portion of the stem attached which does not reveal any division for columnals. It is somewhat like the



elongated columnar segments of pentacrinoid larvae.

The plates of young specimens do not possess the nodose ornamentation found in more mature forms, neither do they reflect the tumidity or incised sutures developed in older specimens. The ratio of cup height to width is considerably reduced in ontogeny.

Radial articular facets of *A. ornatus* are subhorizontal in attitude. Outer ligament furrow is well defined, bordered below by a ridge and above by an uninterrupted transverse ridge. Two large, more or less triangular-shaped muscle areas are present, divided by an intermuscular ridge and bordered by adsutural ridges. Depressed area between radials give a notched appearance to the cup when viewed from above or below. *A. ornatus* in maturity has a rugosity of cup plates not found in *A. typus*.

Measurements in Millimeters

	Holotype SUI35297	Paratype SUI35298	Paratype SUI35299	Paratype SUI35300
Width of cup	5.5	3.7	3.0	2.3
Height of cup	2.6	2.0	1.7	1.4
Ratio H/W	0.47	0.54	0.56	0.60

TYPES.—Holotype SUI35297, paratypes SUI35298, SUI35299, SUI35300 reposited in the Geology Department, The University of Iowa, Iowa City.

OCCURRENCE.—Upper part of Word Formation (between Limestone No. 3 and Limestone No. 4), Upper Permian; about 2 miles northeast of the junction of Hess Canyon with the south branch of Hess Canyon, Hess Canyon quadrangle, Glass Mountains, Texas.

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FIG. 13. *Agnostocrinus ornatus* STRIMPLE, n. sp., ×7.0.

1-3. Immature paratype (SUI35300) viewed from base, summit, and *CD* interray.

4-6. Paratype (SUI35299) viewed from base, *CD* interray, and summit.

7-10. Paratype (SUI35298) viewed from *A* ray, base, *CD* interray, and summit.

11-14. Holotype (SUI35297) viewed from summit, *A* ray, *CD* interray, and base.

PART 8

A CRINOID CROWN FROM D'ORBIGNY'S FAMOUS FOSSIL LOCALITY AT YAURICHAMPI, BOLIVIA

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ABSTRACT

A crinoid crown collected by ERIK N. KJELLESVIG-WAERING from Permian strata (Wolfcampian) at Yaurichampi, near Lake Titicara, Bolivia, and reposited in the Field Museum of Natural History is considered herein. It is a delocrinid with nonspinose axillary primibrachs and is described as *Delocrinus titicara* STRIMPLE & MOORE, n. sp.

INTRODUCTION

The specimen considered here was collected by ERIK N. KJELLESVIG-WAERING in March, 1958, at the locality first made famous by D'ORBIGNY (1842) at Yaurichampi, near Lake Titicara, in the central Andes, Bolivia, and later extensively studied by KOZŁOWSKI (1914), *et al.* Although D'ORBIGNY considered the age of the rocks to be Carboniferous, subsequent studies (e.g., DUNBAR & NEWELL, 1946) on fusulinids, have established an Early Permian (Wolfcampian) age. Fragmentary crinoid remains (chiefly columnals) have been reported from the area but there does not appear to be any reference to complete crinoids. A map of the area is given by DUNBAR & NEWELL (*ibid.*, text-fig. 1).

Family DIPHUICRINIDAE Strimple & Knapp, 1966

Genus DELOCRINUS Miller & Gurley, 1890

TYPE-SPECIES.—*Poteriocrinus hemisphericus* SHUMARD.

DIAGNOSIS.—Dorsal cup low, bowl-shaped; infrabasals small, downflared, confined to pronounced basal concavity; basals large, strongly curved in longitudinal profile, length and width equal, *CD* basal normally truncated for reception of single anal plate (anal *X*); radials moderately large, about twice as wide as long, facets as wide as radials and moderately long with general plane nearby horizontal; anal *X* generally elongate, hexagonal in outline, protruding above radials and followed by single tube plate. Ten arms, biserial, long and branching on primibrach *1* in all rays, exterior of arms gently rounded, with sides distinctly flattened so that they fit tightly together in a vertical position; pinnules slender, moderate in length. Anal sac slender, cylindrical, extending above midheight of arms, terminated by single long, slender spine. Column round.

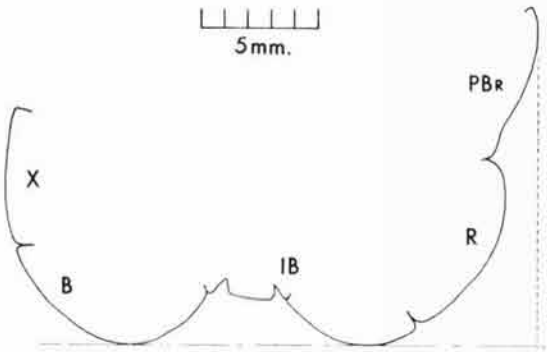
DISCUSSION.—*Delocrinus* typically has primibrach *1* extended as a stout spine; however, by Virgilian time many species no longer produce this feature. STRIMPLE (1961) proposed the genus *Graffhamicrinus* for those forms of delocrinids having ornate surfaces. No species of *Graffhamicrinus* known at this time have a spinose primibrach *1*. KNAPP (1969) attempted to establish a more refined division of the delocrinids and proposed ten new genera. *Diphuicrinus* MOORE & PLUMMER, 1938, has an ornate surface, long slender, subhorizontal anal *X* and typically has uniserial (cuneate brachials) arms.

OCCURRENCE.—Pennsylvanian (Morrowan-Virgilian), Permian; USA, Indonesia.

DELOCRINUS TITICARA Strimple & Moore, n. sp.

Figures 14; 15,*1-3*

DESCRIPTION.—Dorsal cup somewhat deeper than typical for the genus, basal concavity typically deep, arms typical except for primibrachs



which are nonspinose but overhang the cup (see Fig. 14). Ratio of cup height/width 0.34, which is close to *D. major* WELLER with a ratio of 0.35. Each arm becomes biserial with secundibrach *2-3* at which point they are about 5.3 mm wide

FIG. 14. Cross section of *Delocrinus titicara* STRIMPLE & MOORE, n. sp. [Explanation: *IB*=infrabasal; *B*=basal; *R*=radial; *X*=anal *X; PBr*= primibrach *1;* dotted line demonstrates overhang of primibrach *1;* dashed line illustrates basal plane.]

FIG. 15. *Delocrinus titicara* STRIMPLE & MOORE, n. sp.——*1*. Basal view, ×2.5.——*2*. View from *CD* interray.——*3*. View from *A* ray, ×2.0.

and subsequently attain a width of 6.4 mm before commencing to taper toward the distal termination.

Discussion.—*Delocrinus* is typically a smooth form with a low, bowl-shaped cup, axillary primibrach *1* projected and spinelike, secundibrachs equibiserial above most proximal segments which are cuneate. Axillary primibrachs *1* of *D. titicara* are not at all spinose, however, in this regard not differing appreciably from several other Upper Pennsylvanian or Lower Permian species. It appears that the spinose development of primibrach *1* in *Delocrinus* reached its maximum distribution in the Missourian (upper Middle Pennsylvanian) and thereafter some forms within the genus reduced or completely eliminated spinose extension of primibrachs.

Measurements of Holotype in Millimeters

Width of crown (maximum)	25.0
Height of cup	7.5
Width of cup (maximum)	22.0
Width of cup (postero-anterior)	20.8
Diam. basal concavity	10.0
Height of basal concavity	2.2
Length of basal	9.7*
Width of basal	8.0
Length of radial	8.0*
Width of radial	11.5
Length of anal plate	5.5
Width of anal plate (maximum)	3.6

* measurements along surface curvature

Holotype.—Catalogue no. 11626, Field Museum of Natural History, Chicago, Illinois.

Occurrence.—Lower Permian (Wolfcampian); Yauri-champi, near Lake Titicara, central Andes, Bolivia.

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PART 9

PENNSYLVANIAN CRINOIDS FROM THE PINKERTON TRAIL LIMESTONE, MOLAS LAKE, COLORADO

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ABSTRACT

Pennsylvanian crinoids are known from relatively few localities in the western United States. A small fauna of crinoids of Pennsylvanian age now is reported from the Pinkerton Trail Limestone in southwestern Colorado. The fauna includes two species of inadunate crinoids, *Paracromyocrinus molasensis* Strimple & Miller, n. sp., *P.* sp. cf. *P. marquisi* (Moore & Plummer), and one species of a flexible crinoid, *Aexitrophocrinus minuramulosus* Strimple & Miller, n. sp. Conodonts associated with the crinoids indicate an age close to the Atokan-Desmoinesian boundary.

INTRODUCTION

Pennsylvanian crinoids from Oklahoma and Texas have been studied extensively, but relatively little is known about the occurrence of crinoids of this age in the western United States. Recent studies by WEBSTER & LANE (1970), STRIMPLE (1969), WASHBURN (1968), LANE (1964), and TISCHLER (1963), document a few occurrences of crinoids from the Pennsylvanian of southern Nevada, eastern Arizona, southern and central Utah, northern New Mexico, and south-central Colorado. The present study describes a small collection of Pennsylvanian crinoids from southwestern Colorado (Fig. 16). The fauna includes two species of inadunate crinoids, one of which is new, and one new species of flexible crinoid.

This fauna was brought to MILLER's attention by STEVE BURRELL, who collected several specimens in 1966 in connection with thesis research in the area. BURRELL directed MILLER to the locality in 1968, at which time most of the specimens discussed below were collected. CECELIA DULICK visited the locality in 1969 and obtained several additional fragments of calyces. The material described in this study includes MILLER's and DULICK's collections; BURRELL's original collection was not available for study.

LOCATION AND STRATIGRAPHY

All specimens were collected at a single locality about six miles south of Silverton, Colorado, on U.S. Highway 550; the exposure is a roadcut on the northwest side of the highway directly opposite the center of Molas Lake (Fig. 16). The exact location is shown on the Snowdon Peak, Colorado, Quadrangle (1:24,000) at the point where Highway 550 intersects the north edge of the map area.

According to STEVE BURRELL this exposure is within the Pinkerton Trail Limestone (Pennsylvanian), but the exact stratigraphic position within this formation is uncertain. The beds containing the crinoids are dark gray calcilutite and interbedded gray shale containing abundant spiriferoid and productoid brachiopods, planispiral gastropods, and a microfauna of conodonts, fusulinids, and ostracodes.

WENGERD & MATHENY (1958, fig. 20), in a general discussion of the Pennsylvanian System of the Four Corners Region, indicated that the Atokan-Desmoinesian boundary is slightly below the Pinkerton Trail Limestone at this locality. In order to determine more accurately the age of the strata containing the crinoids, CECELIA DULICK collected several samples for conodonts. MILLER processed the samples and sent the conodonts to H. RICHARD LANE who furnished the following identifications and comments (written communication, 1970):

Gnathodus colombiensis (Stibane)
Spathoganathodus coloradoensis Murray & Chronic
Streptognathodus cf. *S. angustus* Dunn
Idiognathodus cf. *I. humerus* Dunn

> "I would say that the conodont fauna strongly suggests an Atokan age, but a lower Des Moines determination cannot be ruled out."

From all evidence it appears that the crinoid fauna is from strata very close to the Atokan-Desmoinesian boundary.

ACKNOWLEDGMENTS

Our thanks are extended to those who have cooperated: STEVE BURRELL, Wisconsin State University at River Falls, who brought the locality to the attention of MILLER; CECELIA DULICK of Dearborn Heights, Michigan, who collected and made available several crinoids and conodont samples; DAVID L. CLARK, University of Wisconsin, who provided facilities for processing the conodont samples; and H. RICHARD LANE, Amaco Production Company, Tulsa, Oklahoma, who kindly identified the conodonts and interpreted their age.

SYSTEMATIC DESCRIPTIONS

Class CRINOIDEA Miller, 1821

Subclass INADUNATA Wachsmuth & Springer, 1885

Order CLADIDA Moore & Laudon, 1943

Family CROMYOCRINIDAE Bather, 1899

Genus PARACROMYOCRINUS Strimple, 1966

PARACROMYOCRINUS MOLASENSIS Strimple & Miller, n. sp.

Figures 17,*1-2*

DESCRIPTION.—Dorsal cup medium-sized, bowl-shaped, sides of cup erect, base invaginated. Infrabasal circlet horizontal, extending well be-

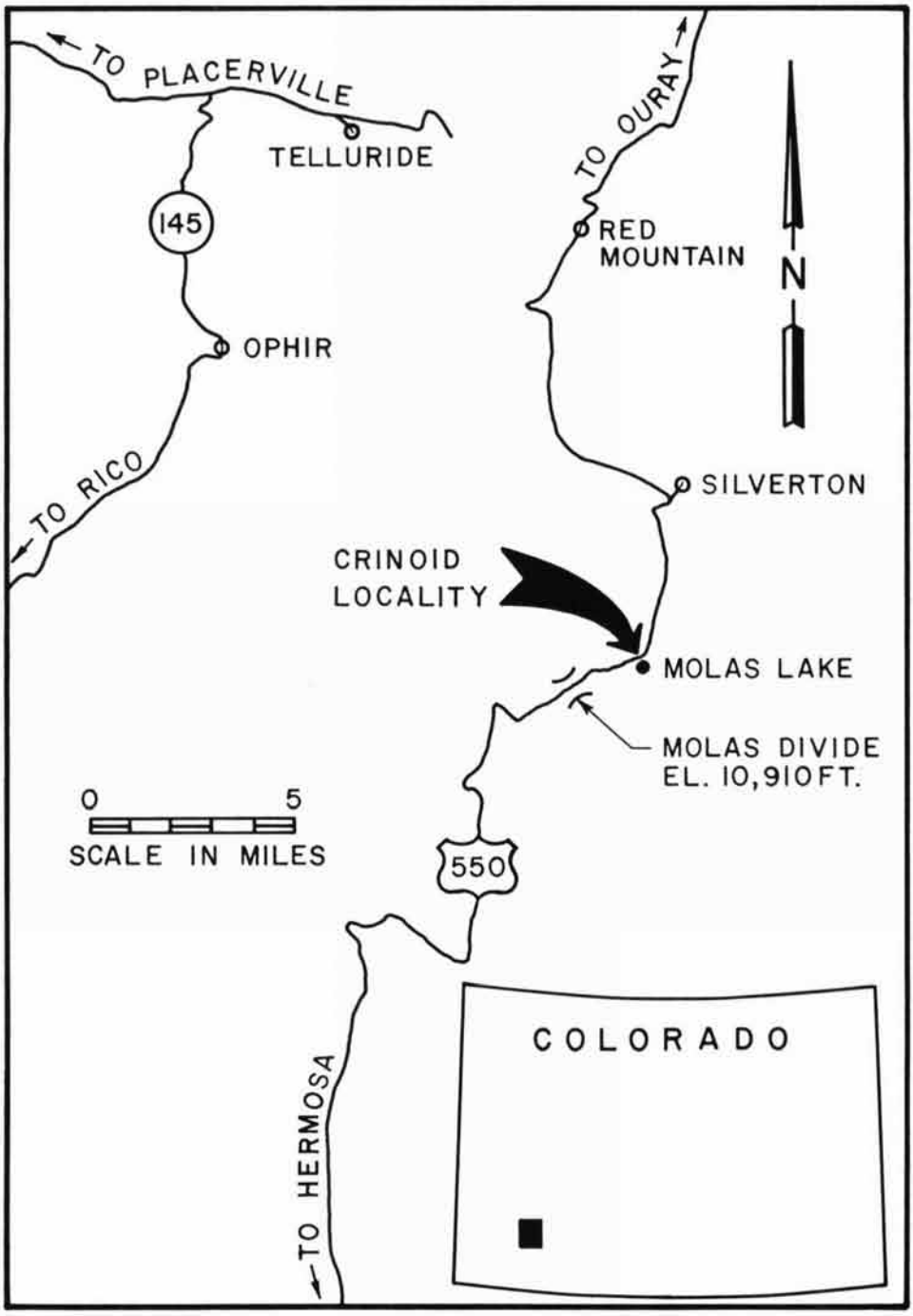
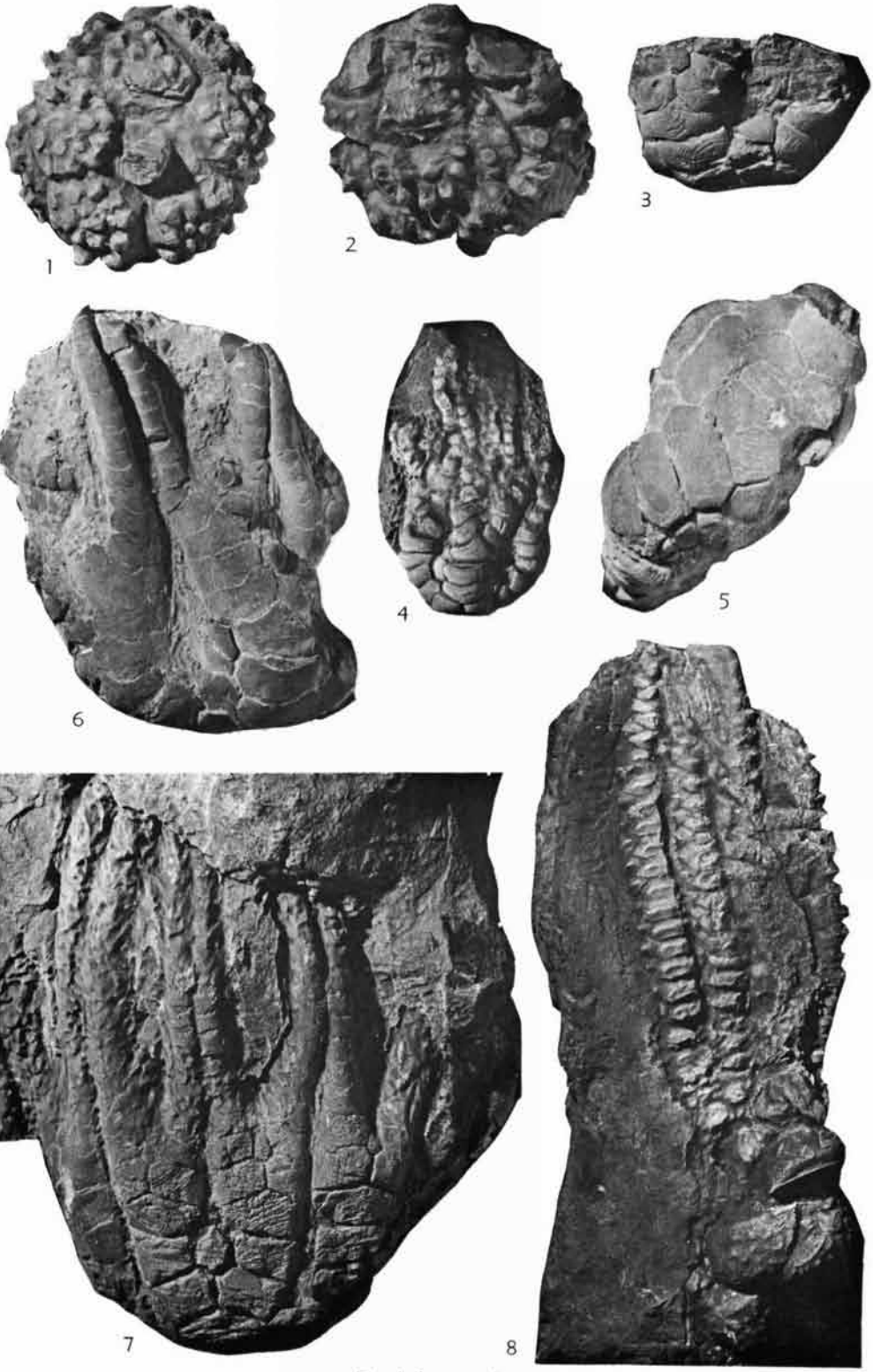


FIG. 16. Location of the Pinkerton Trail Limestone exposure near Molas Lake in southwestern Colorado.



(See facing page.)

yond proximal column (which is in place); basals very large, proximal ends form sides of basal concavity as well as broad basal plane and extend well up in the lateral walls of calyx, posterior basal narrow (due to encroachment of the large radianal) and truncated above for contact with anal *X*; radials wide, proximal tips well above basal plane, distal ends curving slightly inward to outer ligament area, but not forming a shelf; 2 anal plates, radianal long and quadrangular encroaching on both posterior (*CD*) basal and *C* radial; anal *X* elongated extending well above cup. Arms ten, uniserial as far as preserved (to secundibrach *4*). Primibrach *1* axillary, almost twice as wide as high, overhanging the cup and having low-angled facets above. Ornamentation of cup and arms comprised of long rounded nodes over 1 mm in length and somewhat smaller in diameter.

Discussion.—*P. molasensis* has a cup with configuration much like that of *Dicromyocrinus texasensis* (Moore & Plummer, 1940); however, the latter is proportionately shallower and the infrabasal circlet proportionately wider. Strimple & Watkins (1969, p. 163) described a specimen as *D.* sp. cf. *D. texasensis* from the Marble Falls Formation (Atokan) with uniserial brachials and 3 anal plates in the cup. *Paracromyocrinus molasensis* has 2 anal plates. *P. marquisi* (Moore & Plummer, 1940), is also comparable but is slightly more advanced in that there is a more pronounced basal concavity than found in *P. molasensis*. The ornate surface of *P. marquisi* is composed of moderately large, scattered nodes and is finely granular, whereas *P. molasensis* has more pronounced nodes. Only a few secundibrachs are preserved in the holotype of *P. molasensis* but there are at least 3 uniserial segments. The arms of *P. marquisi* are biserial with secundibrach 2.

Measurements of Holotype in Millimeters

Height and width of cup	10.8, 19.6
Width of IBB circlet	6.7
Length of basal	8.1
Length of basal (along surface)	12.0
Width of basal	9.0
Width and length of radial	9.8, 5.2
Length of radianal	6.9
Max. width of radianal	4.6
Diam. proximal columnals	3.1
Length of anal *X*	6.0
Width of anal *X* (maximum)	4.2

Holotype.—SUI34687, collected by J. F. Miller, reposited Geology Department, The University of Iowa, Iowa City.

Occurrence and Horizon.—Pinkerton Trail Limestone, Pennsylvanian (see Introduction).

PARACROMYOCRINUS sp. cf. P. MARQUISI (Moore & Plummer), 1940

Figure 17,*8*

Discussion.—A single poorly preserved crown is assigned to *Paracromyocrinus* sp. cf. *P. marquisi*, based on ornamentation of the arms and the few cup plates preserved. The cup plates and lower arm segments are covered by widely spaced low nodes. Upper arms are equibiserial and horizontal ridges are found at midheight of each brachial. The specimen possibly represents a transitional stage between *P. molasensis* of Atokan age and *P. marquisi* of early Desmoinesian age. The holotype of *P. marquisi* is from an unknown horizon but hypotypes have been described by Strimple (1968, p. 33) from the Savanna Formation, Desmoinesian, of Oklahoma.

Hypotype.—SUI34688, collected by J. F. Miller, reposited in Geology Department, The University of Iowa, Iowa City.

Occurrence.—Pinkerton Trail Limestone, Pennsylvanian (see Introduction).

Fig. 17. *Paracromyocrinus* and *Aexitrophocrinus* from the Pinkerton Trail Limestone, Molas Lake, Colorado.

1-2. Paracromyocrinus molasensis Strimple & Miller, n. sp., Pinkerton Trail Limestone, Molas Lake, Colo., holotype (SUI34687); *1*, basal view; *2*, posterior, *ca.* ×1.9.

3-7. Aexitrophocrinus miniramulosus Strimple & Miller, n. sp., Pinkerton Trail Limestone, Molas Lake, Colo.; *3*, posterior view of paratype (SUI34689); *4*, side view of crown (*CD* interray to right), paratype (SUI35141); *5*, basal view *CD* interray at summit; *6*, view of *DE* interray, holotype (SUI34686); *7*, side view of large crown, paratype (SUI34690), *ca.* ×1.4.

8. Paracromyocrinus sp. cf. *marquisi* (Moore & Plummer), Pinkerton Trail Limestone, Molas Lake, Colo.; hypotype (SUI34688); side view of partial crown, *ca.* ×1.6.

Subclass FLEXIBILIA Zittel, 1895
Order SAGENOCRINIDA Springer, 1913
Family DACTYLOCRINIDAE Bather, 1899
Genus AEXITROPHOCRINUS Strimple & Watkins, 1969

AEXITROPHOCRINUS MINURAMULOSUS
Strimple & Miller, n. sp.
Figure 17,*3-7*

DESCRIPTION.—The 3 infrabasals and most of the basals are covered by the proximal columnals. The 5 basals are restricted to the columnal cicatrix except for *CD* basal, which is elongated, and the distal apices of the other 4 plates. Anal *X* is moderately large, extends about 0.3 the height of the radials, and is followed by 2 plates above, which apparently are followed by several smaller plates (one preserved in right series). In other interrays there is one interradial, smaller than anal *X*, followed by 2 which are subsequently followed by 1 or 2 plates. In the intersecundibrach range one interbrach is followed above by 2 or 3 plates. The arms branch once on primibrach *2* and again on secundibrach *3* in all rays. Ramules do not develop until tertibrach *4-5*, thereafter every other brachial, or rarely the third, bears a relatively small ramule on the inner side of each half-ray.

DISCUSSION.—*Aexitrophocrinus minuramulosus* differs from the Desmoinesian *A. formosus* (MOORE & PLUMMER, 1940), in that the posterior basal is not quite as long and the radials reach the columnar cicatrix. In *A. formosus* the proximal ends of the radials do not normally touch the columnar cicatrix, and a portion of the lateral sides of the basals extend beyond the attachment circlet. *A. lamberti* STRIMPLE & WATKINS, 1969, of the Marble Falls Formation (Atokan) also has basal plates exposed well beyond the columnar attachment area and has a lesser number of interradial and interbrachial plates than occur in *A. minuramulosus*.

TYPES.—Holotype SUI34686, paratypes SUI34689, SUI 34690, SUI35141, collected by J. F. MILLER, reposited Geology Department, The University of Iowa, Iowa City.

OCCURRENCE AND HORIZON.—Pinkerton Trail Limestone, Pennsylvanian (see Introduction).

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