UNIVERSITY OF KANSAS PALEONTOLOGICAL CONTRIBUTIONS
ECHINODERMATA, ARTICLE 1, PAGES 1-23, PLATES 1-6, FIGURES 1-4

NEW GENERA OF MISSISSIPPIAN CAMERATE CRINOIDS

By ARTHUR L. BOWSHER [1]

CONTENTS

1. U. S. National Museum, Washington, D. C.; formerly, University of Kansas. Published by permission of the Secretary of the Smithsonian Institution.

ILLUSTRATIONS

ABSTRACT

Three new genera of camerate crinoids, *Aacocrinus, Cusacrinus* and *Nunnacrinus* are described and referred to the family Actinocrinitidae AUSTIN & AUSTIN, 1842. Many species of actinocrinitids formerly referred to other genera are reassigned to these three new genera. Type specimens from the C. A. White collection in the U. S. National Museum, briefly described but not illustrated by JAMES HALL, are figured for the first time.

INTRODUCTION

In studying Mississippian crinoids assigned to the Actinocrinitidae AUSTIN & AUSTIN, 1842, I discovered that numerous species are not properly referred to currently recognized genera. It is necessary to recognize several new genera for these species in order to complete a discussion of the classification, evolution, and stratigraphic range of the actinocrinitids. The primary purpose of this paper is to describe three new genera and two new species of actinocrinitids. A second purpose is to illustrate and discuss several species described briefly but never illustrated by HALL (1861a-c), which are referred to new genera in this paper.

SYSTEMATIC DESCRIPTIONS

SUBCLASS **CAMERATA** WACHSMUTH & SPRINGER, 1885

ORDER **MONOBATHRA** MOORE & LAUDON, 1943

FAMILY **ACTINOCRINIDITAE** AUSTIN & AUSTIN, 1842

GENUS **AACOCRINUS** BOWSHER, n. gen.

?Actinocrinus (MILLER), 1821 *(pars)*, MILLER, 1892a, p. 672; 1892b, p. 18; 1894, p. 272; 1897, p. 731. ——— MILLER & GURLEY, 1897, p. 36. ——— WACHSMUTH & SPRINGER, 1897, p. 570.
Actinocrinus (MILLER), 1821 *(pars)*, WELLER, 1898, p. 57-63. ——— PECK & KEYTE, 1938, p. 81-89.
Actinocrinites MILLER, 1821 *(pars)*, BASSLER, 1938, p. 33. ——— BASSLER & MOODEY, 1943, p. 268, 271, 274. ——— MOORE & LAUDON, 1944, p. 193, pl. 77, fig. 12, 13.
Melocrinus (GOLDFUSS), 1826 *(pars)*, MILLER & GURLEY, 1895b, p. 55. ——— MILLER, 1897, p. 748. ——— WELLER, 1898, p. 348. ——— WILSON, 1916, pl. 2, fig. 8. ——— BASSLER & MOODEY, 1943, p. 271, 561.
Blairocrinus MILLER, 1891 *(pars)*, MILLER & GURLEY, 1893, p. 28.

Type species.—*Aacocrinus nododorsatus* BOWSHER, new species.

Generic diagnosis.—Actinocrinitids with conical cup, low arched tegmen, protuberant ray, *Amb* tracts 10 to 15 or more, and prominent anal tube.

Description.—Actinocrinitids with moderately conical dorsal cup and low, arched tegmen. $IBrr_1$ distinctly hexagonal; $IBrr_2$ pentagonal and axillary. Divisions of the ray above $IIbrr_1$ quite variable, some species having arms arising directly above the $IIBrr_1$ or $IIBrr_2$ whereas some have *AxIIBrr* and arms arising from *IIIBrr*. Interray plates regularly polygonal with rays separated at arm level by two or three regularly polygonal interradial plates. *iBr* plates are not present within the rays. Distal surfaces of terminal plates of the calical portion of the ray with distinct fossae for muscles, dorsal ligaments, interarticular ligaments, and articular ridges (Pl. 1, fig. 2*d*; text figure 2). Although the arms are not known, it is believed that these articular surfaces supported massive unbranched biserial arms.

The low arched tegmen is composed of large, regularly polygonal plates. The outer surface of some plates is flat and smooth but on others produced into a prominent node. The nodose character of the tegminal plates varies from species to species. Some have three prominent, nodose tegminal plates overlying the ambulacral tract just above the ambulacral openings (Pl. 1, fig. 2*a*). Most species have a small conspicuous anal tube composed of small regularly polygonal plates located slightly posterior to the center of the tegmen (Pl. 1, fig. 2*a*). The anal tube is not preserved on the specimens studied and its true character is unknown.

Aacocrinids have 10 to 15 or more arms, which are believed to be biserial and unbranched.

The character of the column is unknown.

The aacocrinids are medium-sized, ranging from 16 to 35 mm in height. The width of most specimens is less than the height.

Remarks.—This interesting group of crinoids has been placed previously in *?Actinocrinus* (MILLER, 1891, p. 18; MILLER, 1892a, p. 672; MILLER, 1894, p. 272; WACHSMUTH & SPRINGER, 1897, p. 570), *Actinocrinus* (WELLER, 1898, p. 272; MILLER & GURLEY, 1897, p. 36; PECK & KEYTE, 1938, p. 81-89), *Actinocrinites* (BASSLER & MOODEY, 1943, p. 268, 271, 274), *Dorycrinus* (KEYES, 1894, p. 64), and *Melocrinus* (MILLER & GURLEY, 1895a, p. 55; WELLER, 1898, p. 348; WILSON, 1916, pl. 2, fig. 8). It is difficult to decide what to do with this group of crinoids because of the simplicity of their ray structure. The majority of specimens have an actinocrinitid type of posterior interradius consisting of an anal plate followed by two regularly polygonal plates. Aacocrinids resemble *Stiptocrinus* (KIRK, 1946) in structure of the ray, interradial areas, and tegmen. The posterior interradius of *Stiptocrinus* differs from that of *Aacocrinus* in being typically like that of periechocrinitids, with an anal plate followed by three regularly polygonal plates.

Some specimens of *Aacocrinus* (for example, the form called *Melocrinus sampsoni* MILLER & GURLEY, 1895a, p. 55), have four BB and hence a basal circlet resembling that of *Melocrinus*. The presence of four BB in such groups as the actinocrinitids and batocrinids is anomalous but does occur (WILSON, 1916, pl. 11, fig. 7, 8, 10, 11).

One cannot rule out the possibility that the aacocrinitids were derived from forms similar to *Stiptocrinus* (Periechocrinitidae) or *Melocrinus* (Melocrinitidae). However, the differences between the

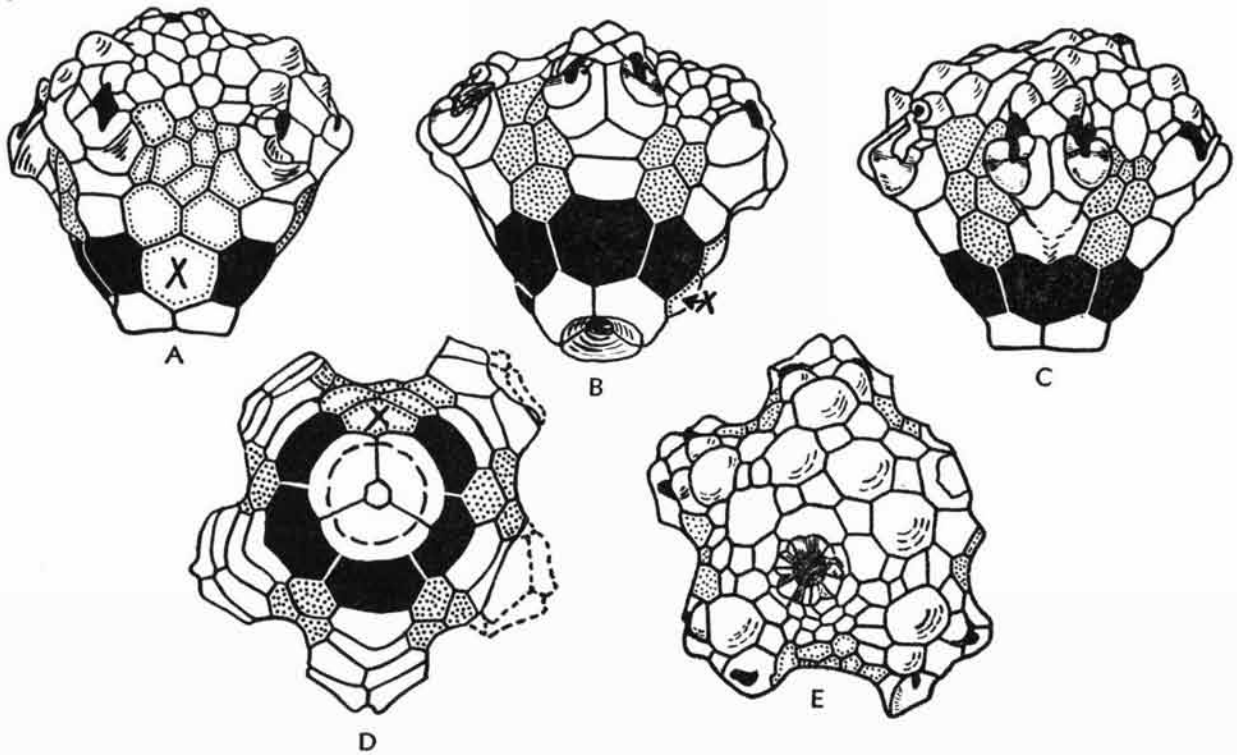


FIGURE 1. Diagrams showing form and structure of *Aacocrinus nododorsatus* (type species of *Aacocrinus*), from the Chouteau limestone near Sedalia, Mo. (USNM Springer Coll., no. S4,606). *A*, Posterior view of interradial area. *B*, Left anterior ray in oblique view. *C*, Left anterior view with calyx upright. *D*, Basal view. *E*, Top view. All figures ×2.

structure of the posterior interradius of each of these groups and that of the aacocrinids suggests that the latter forms are not closely related to either the stiptocrinids or melocrinitids. I think that the gross similarity between the stiptocrinids and the aacocrinids is a result of convergent trends of evolution in two distinctly different groups of crinoids. The rare occurrence of four BB in aberrant actinocrinitids does not indicate that they had a melocrinitid ancestry.

Some species of *Aacocrinus* superficially resemble species of *Blairocrinus* MILLER (1891) and *Sampsonacrinus* MILLER & GURLEY (1895b). *Aacocrinus* differs from *Blairocrinus* in having a conical dorsal cup, variable upper part of the calical portion of the ray, 10 ambulacral tracts, and a different type of tegmen. The dorsal cup of *Blairocrinus* varies from low and conical to nearly flat. The isotomous divisions of the blairocrinid invariably supports four arms to each ray, 20 arms to the specimen. The tegmen of *Blairocrinus* is conical and developed into a strong anal tube. The outer surfaces of all tegminal plates are smooth and flat, except for three tegminal plates (located just above the ambulucral openings) which are developed into large prominent spines. The anal tube of *Blairocrinus* is centrally located on the tegmen.

Sampsonocrinus differs from *Aacocrinus* in having a globose or bowl-shaped dorsal cup, strongly protuberant arm trunks, and a more highly ramified *Amb* tract. The plates of the tegmen of *Sampsonocrinus* tend to be spinose, whereas those of *Aacocrinus* generally are nodose.

Aacocrinids superficially resemble *Actinocrinites* and *Steganocrinus* but differ in structure of the upper part of the calical portion of the ray. *Actinocrinites* has six arms to each ray, 30 in all. *Aacocrinus* has only 10 to about 15 arms. The upper part of the calical portion of the ray of *Steganocrinus* is extended into a bizarre trunk and supports many small short incurling arms.

Distribution.—All species assigned to the genus *Aacocrinus* are reported from the Chouteau limestone or Chouteau group of Missouri. BRANSON (1938, fig. 16) considered nearly all pre-Burlington Lower Mississippian strata of Missouri as a part of the Chouteau formation. KAISER (1950, p. 2170) presents evidence that the upper Kinderhookian strata of southwestern Missouri include two distinct stratigraphic units, Chouteau limestone (restricted) and an overlying Northview-Sedalia sequence. KAISER (1950, p. 2143) lists *A. arrosus* (MILLER), *A. boonensis* PECK & KEYTE and *A. trifugis* (MILLER) from the Chouteau, which is the lower part of the upper Kinderhookian rocks in southwestern Missouri and he (loc. cit., p. 2151) records only "a relatively few primitive species of *Actinocrinites*," from the overlying Sedalia, which is late Kinderhookian in age.

Numerous collections of crinoids from the Chouteau formation which I have studied contain genera and species that are well known in this stratigraphic unit (PECK & KEYTE, 1938). Most specimens studied were recorded merely as from the Chouteau formation, for most workers have not recognized subdivisions within what they called the "Chouteau formation" or "Chouteau group." No specimens were listed from the Sedalia. Most of the early collections, which were made by R. A. BLAIR, J. H. BRITTS, and F. A. SAMPSON, are labeled "Chouteau limestone at Sedalia, Mo." Recently I had the opportunity of visiting Miss Jessie Blair, daughter of R. A. Blair, at Sedalia, Mo., and hearing from her many tales of fossil collecting in the Sedalia area. According to Miss Blair, her father and others collected from old quarries, now abandoned and grown over, north of Sedalia on the Georgetown road and from Sweeney quarry near Clifton City, Mo. She remarked that her father always considered Sweeney quarry as the best place to collect. The old quarries north of Sedalia are mainly in the Sedalia formation,[1] but both the Chouteau and Sedalia formations are exposed in the Sweeney quarry, although most fossils currently available at the latter place are from the Chouteau.

During August, 1952, in company with W. T. Allen of the U. S. National Museum, I spent several weeks studying the distribution of crinoids in the Chouteau, Sedalia, Northview and Pierson strata in the vicinity of Sedalia, Warsaw and Osceola, Mo. Dr. E. L. Clark and Dr. T. R. Beveridge furnished much information concerning the stratigraphic succession and fossil localities. They also turned over to me several interesting crinoids that had been collected in the course of their studies of Lower Mississippian rocks in southwestern Missouri.

Beveridge (1951, p. 33) states that in the Weaubleau Creek area no evidence of an unconformity is found between the Chouteau and overlying Sedalia strata. He believes the lithological contact to be transitional and the faunas similar.

In southwestern Missouri I recognize the same sequence of Lower Mississippian rocks as in the Weaubleau Creek area. The Chouteau seems here to grade upward into the Sedalia, which in turn grades laterally and vertically into the Northview shale. Species of *Aacocrinus* were found throughout the Chouteau formation and well up into overlying Sedalia beds. *A. boonensis* was found throughout the Chouteau and into lower beds of the Sedalia, but *A. chouteauensis* and *A. sampsoni* were observed only in the upper beds of the Chouteau. *A. nododorsatus* was not found, but is believed to be from the Chouteau. *A. spinosulus* was collected from the upper part of the Chouteau and lower part of the Sedalia. None of these species were found in the upper Sedalia. The upper beds of the Sedalia yielded what is believed to be a new genus of actinocrinitids closely related to *Aacocrinus* but it is not described here. Several internal molds of batocrinids, a species of *Dichocrinus*, a new species of *Eretmocrinus*, and several new species of *Nunnacrinus* were obtained from upper beds of the Sedalia; none occur in the underlying Chouteau.

The currently recognized range of *Aacocrinus* is throughout the Chouteau formation and well up into the overlying Sedalia formation. It is believed that the genus is absent from topmost beds of the Sedalia. WACHSMUTH & SPRINGER (1897, p. 570) list *A. chouteauensis* from the Burlington. This citation is believed to be erroneous. *Aacocrinus* has not been found in the Northview, Pierson, St. Joe, Fern Glen, Reeds Spring, or Burlington formations. *Aacocrinus* has been reported only from Missouri and is not reported from Kinderhookian strata elsewhere.

Aacocrinus boonensis (PECK & KEYTE) BOWSHER, n. comb.

Actinocrinus boonensis PECK & KEYTE, 1938, p. 89, pl. 28, fig. 21, 22.
Actinocrinites bonoensis (PECK & KEYTE) (misspelling) BASSLER & MOODEY, 1943, p. 628.
Actinocrinites boonensis (PECK & KEYTE) MOORE & LAUDON, 1944, p. 193, pl. 77, fig. 12.

Occurrence.—Chouteau limestone, Easley, Mo.
Holotype.—4447, University of Missouri.

Aacocrinus chouteauensis (MILLER) BOWSHER, n. comb.

Actinocrinus? chouteauensis MILLER, 1892b, p. 18, pl. 3, fig. 9-11; 1892c, p. 672, figs. 1203-1205; 1894, p. 272, pl. 3, figs. 9-11.
Dorycrinus chouteauensis (MILLER) KEYES, 1894, p. 169.
?Actinocrinus chouteauensis MILLER, WACHSMUTH & SPRINGER, 1897, p. 570, pl. 46, fig. 11*a-b*.
Actinocrinus chouteauensis MILLER, WELLER, 1898, p. 57.
——— PECK & KEYTE, 1938, p. 81, pl. 27, fig. 16, 17.
Actinocrinites chouteauensis BASSLER & MOODEY, 1943, p. 268.

Occurrence.—Chouteau limestone, Sedalia, Mo.
Holotype.—6957, Walker Museum, University of Chicago.

Aacocrinus milleri (PECK & KEYTE) BOWSHER, n. comb.

(See *Aacocrinus sampsoni* (MILLER & GURLEY))

Aacocrinus nododorsatus BOWSHER, n. sp.

Plate 1, figures 2*a-e*, 3*a-e*; text figs. 1, 2

Diagnosis. — A small species with moderately conical dorsal cup, low-arched tegmen, angular *BB*, plates broadly arched, median ray ridge, markedly protuberant ray, two arms to each ray, massive plates, wide interradial areas, and nodose tegminal plates.

Description.—*BB* angular along proximal edge for reception of a relatively large column, approximately 5.9 mm in diameter. *RR* heptagonal, broadly arched, and smooth, except for median ray ridge which originates on the distal part of each *R*.

1. T. Beveridge, oral communication, 1952.

IBrr$_1$ hexagonal, wider than long, broadly arched, and with a distinct median ridge. *IBrr*$_2$ hexagonal, wider than long, broadly arched, and marked by conspicuous angular median ridge. *IIBrr*$_1$ axillary, pentagonal, broadly rounded, with median ridge disappearing toward distal edge. *IIBrr*$_1$ form part of the projecting calical portion of the ray and begin to take on the conformation of the arm. *IIBrr*$_2$ cuneiform, taking on conformation of the arm. Distal surfaces of the *IIBrr*$_2$ have distinct muscle and ligament fossae and fulcral ridges (Fig. 2; Pl. 1, fig. 2*d*). The arms, which are believed to be biserial and unbranched, arise directly from the distal surfaces of the *IIBrr*$_2$.

The plates of the posterior interradius are X + 2 + 4 + 2. The plates of the posterior interradius of the holotype do not show accurately the shape of their outer surface, as the hard semilithographic limestone which covered these plates was taken off by needle and dental tools. However, the shape of these plates is the same as those of plates belonging to the *la* interradius, which is broadly rounded, with faint radiating ridges and a weak central node or boss (Pl. 1, fig. 2*d*).

Three regularly polygonal plates lie between each ray in the cup. The lowermost is hexagonal and the succeeding ones pentagonal. The plates between the rays are openly connected with plates of the tegmen. All plates of the cup and tegmen are massive and the calyx retains its true shape well because of the rigidity of the cup and tegmen.

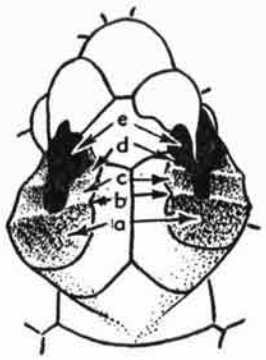


FIGURE 2. Articular facets of first secundibrachs (IIBrr$_1$) of *Aacocrinus nododorsatus*, left anterior view (see Pl. 1, fig. 2*d*); *a*, fossa for dorsal ligament; *b*, articular ridges; *c*, fossae for interarticular ligaments; *d*, muscular fossa; *e*, ambulacral openings; ×1.5.

All plates of the cup and tegmen, except those of the anal tube, are large in proportion to size of the calyx.

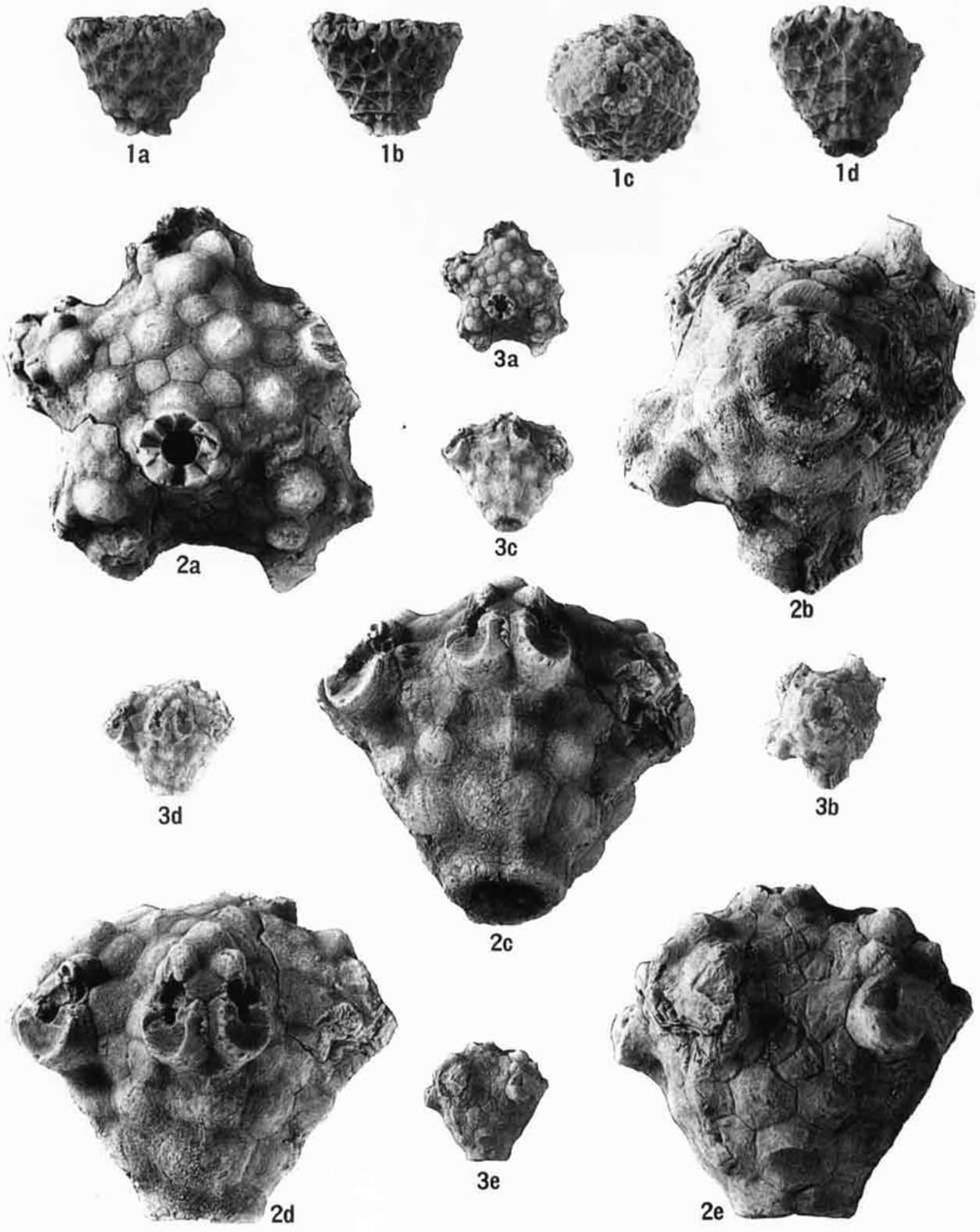
The height of the holotype of *Aacocrinus nododorsatus* from the proximal surface of the *BB* to the base of the anal tube is approximately 17.9 mm. The height to the base of the *Amb* openings is 11.2 mm. The diameter, exclusive of the projecting rays, is 16.9 mm and the greatest diameter at the base of the arms is approximately 23.6 mm. The width of the projecting part of the ray just below the arms is 7.1 mm and the width between the rays at arm level is 4.4 mm. The rays project approximately 2.5 mm beyond the general outline of the calyx. The *BB* are approximately 1.7 mm long and the basal circlet is 7.2 mm in diameter. The cicatrix of the column is 5.9 mm in diameter. The *RR* are 4.8 mm long and 6.5 mm wide. The *IBrr*$_1$ are 2.7 mm long and 4.4 mm wide. The *IBrr*$_2$ are approximately 2.2 mm long and 4.6 mm wide. The anal plate is 5.1 mm long and 4.7 mm wide. The arms appear to have been 3.9 mm wide at the base. Some of the nodes on plates of the tegmen extend to 2.5 mm above the general surface of the tegmen. The base of the anal tube is 4.5 mm in diameter. The so-called radial dome plates are about 4 mm in diameter, approximately twice as large as other tegminal plates.

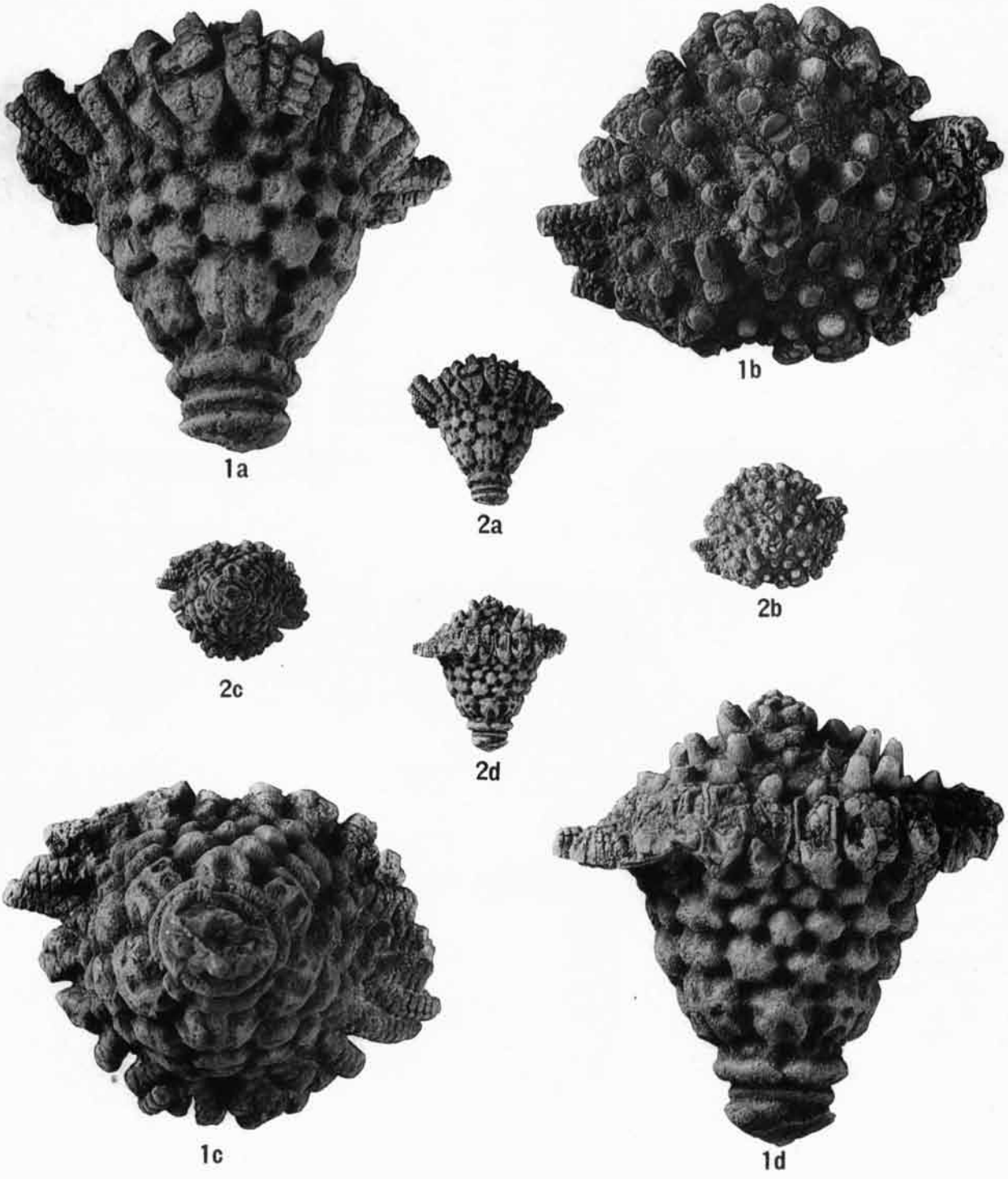
The surface ornamentation of plates is not preserved except on some of the tegminal plates, which have a finely granulose surface that probably is characteristic of the entire surface of the calyx. One tegminal plate retains a single row of slightly larger granules around the margin of the plates (Pl. 1, fig. 2*a*).

The characters of the columnals and arms are not known. The arms are probably biserial and unbranched, as in most actinocrinids. They seem to have been very massive in comparison to the size of the calyx.

Remarks.—This species most closely resembles *Aacocrinus spinosulus*. It differs in having a weaker median ray ridge, more conical dorsal cup, more protuberant ray, lower arched tegmen, smaller arms, narrower interradial area, nodes rather than spines on the plates of the tegmen, and more plates in the tegmen. As compared to other species, *A. nododorsatus* is smaller (*A. boonensis* excepted), has the median ray ridge slightly more distinct

EXPLANATION OF PLATE 1


1a
1b
1c
1d
2a
3a
3c
2b
3d
2c
3b
2d
3e
2e



BOWSHER — Mississippian Camerate Crinoids

(except for *A. sampsoni*), a narrower interradial area at arm level, more massive arms, more protuberant rays, more distinct nodes on tegminal plates, and greater number and more highly differentiated tegminal plates than *A. senectus, A. chouteauensis, A. sampsoni* and *A. boonensis.* The articular surfaces on IIBrr are better developed on *A. nododorsatus* than on any other species. The dorsal cup of *A. nododorsatus* is less conical than that of *A. chouteauensis, A. boonensis* and *A. senectus,* but the shape is similar to that of *A. sampsoni.* The ratios of diameter of calyx at arm level (excepting protuberant rays) to height at *Amb* openings are as follows: *A. boonensis,* 1.5; *A. chouteauensis,* 1.28; *A. nododorsatus,* 1.67; *A. senectus,* 1.18; and *A. sampsoni,* 1.66. The distance between the lateral margins of the ray as compared to height of the cup of *A. nododorsatus* seems to be one third less than that of *A. sampsoni.*

Occurrence.—The holotype and only specimen from the G. Hambach Collection is listed from the Chouteau limestone, near Sedalia, Mo.

Holotype.—S4,606, Springer Collection, U. S. National Museum, Washington, D. C.

Aacocrinus sampsoni (MILLER & GURLEY) BOWSHER, n. comb.

Melocrinus sampsoni MILLER & GURLEY, 1895b, p. 55, pl. 2, fig. 27-29. ——— MILLER, 1897, p. 748. ——— WELLER, 1898, p. 348. ——— WILSON, 1916, pl. 2, fig. 8.
Actinocrinus milleri PECK & KEYTE, 1938, p. 83-84, pl. 27, fig. 14, 15.
Actinocrinites milleri (PECK & KEYTE) BASSLER & MOODEY, 1943, p. 271.

PECK & KEYTE (1938, p. 83) assigned *Melocrinus sampsoni* MILLER & GURLEY, 1895, to the genus *Actinocrinus* and proposed a new name, *Actinocrinus milleri* for this species: both names are based on the same holotype. They gave no reason for this change of names. Presumably the new name was proposed to replace the name *Actinocrinus sampsoni* (MILLER & GURLEY), 1895a, because of homonymy with the name *Actinocrinites sampsoni* (MILLER & GURLEY), 1896c. The name *Actinocrinus milleri* has no validity because it was proposed to replace the earlier of a pair of homonyms. *Actinocrinus sampsoni* (MILLER & GURLEY), 1895, is referred to the genus *Aacocrinus* and *Actinocrinus sampsoni* MILLER & GURLEY, 1896c, belongs to the genus *Nunnacrinus.* Currently no homonymy exists; so both names are considered as available and are used in this paper (HEMMING, 1950, p. 105, 121).

Occurrence.—Chouteau limestone, Sedalia, Mo.

Holotype.—6958, Walker Museum, University of Chicago.

Aacocrinus senectus (MILLER & GURLEY) BOWSHER, n. comb.

Actinocrinus senectus MILLER & GURLEY, 1897, p. 36, pl. 2, fig. 23-25. ——— WELLER, 1898, p. 63. ——— PECK & KEYTE, 1938, p. 85-86, pl. 27, fig. 12-13.
Actinocrinites senectus (MILLER & GURLEY) BASSLER & MOODEY, 1943, p. 274.

Occurrence.—Chouteau limestone, Sedalia, Mo.

Holotype.—4010, University of Cincinnati.

Aacocrinus spinosulus (MILLER & GURLEY) BOWSHER, n. comb.

Blairocrinus spinosulus MILLER & GURLEY, 1893, p. 28, pl. 7, fig. 16-18.
Blairocrinus spinulosus (misspelling) MILLER & GURLEY, WELLER, 1898, p. 149.
Actinocrinus spinulosus (misspelling) (MILLER & GURLEY), PECK & KEYTE, 1938, p. 88-89, pl. 28, fig. 23-25.
Actinocrinites spinulosus (misspelling) (MILLER & GURLEY) BASSLER & MOODEY, 1943, p. 274. ——— MOORE & LAUDON, 1944, pl. 77, fig. 13.

The name of this species was originally given as *spinosulus* by MILLER & GURLEY (1893, p. 28, pl. 7, fig. 16-18). WELLER (1898, p. 149) erroneously cites "1894. *Blairocrinus spinulosus.* Miller and Gurley, Bull. no. 3, Ill. State Mus. Nat. Hist., p. 28, pl. 7, figs. 16-18." Subsequent workers have also cited this species as *Actinocrinus spinulosus* (MILLER & GURLEY) (PECK & KEYTE, 1938, p. 88) and *Actinocrinites spinulosus* (MILLER & GURLEY) (BASSLER & MOODEY, 1943, p. 274). The correct specific name for this species is *spinosulus.* The name *Actinocrinus spinosulus* (MILLER & GURLEY), 1893, is a homonym of *Actinocrinus spinosulus* HALL, 1860 (P. 52). Currently there is no homonymy, because *Blairocrinus spinosulus* MILLER & GURLEY, 1893, is referred in this paper to the genus *Aacocrinus;* the two species are not congeneric.

Occurrence.—Chouteau limestone, Sedalia, Mo.

Holotype.—Walker Museum, University of Chicago, 6601.

GENUS **CUSACRINUS** BOWSHER, new genus

Actinocrinites MILLER, 1821 (*pars*); AUSTIN & AUSTIN, 1842, p. 109; 1843, p. 200. ——— MEEK & WORTHEN, 1869, p. 155; 1873, p. 342.
Actinocrinus MILLER, 1821 (*pars*) HALL, 1859, p. 585; HALL, 1860, p. 10, 16, 35, 86, pl. 2, fig. 1. ——— Mc-

---

EXPLANATION OF PLATE 2

FIGURE PAGE

1.—*Cusacrinus nodobrachiatus* (WACHSMUTH & SPRINGER), S4,605, lectotype chosen from the type lot, Springer collection, from the Hampton formation, Le Grand, Iowa. *1a,* anterior ray, oblique view. *1b,* top view. *1c,* basal view. *1d,* posterior interradial area. All figures × 3 14

FIGURE PAGE

2—*Cusacrinus nodobrachiatus* (WACHSMUTH & SPRINGER), same specimen as in figure 1. *2a,* anterior ray, oblique view. *2b,* top view. *2c,* basal view. *2d,* posterior interradial area. All figures × 1 14

CHESNEY, 1860, p. 24. ——— HALL, 1861a, p. 2, 11, 12; 1861b, p. 2, 11, 12; 1861c, p. 277, 268. ——— HALL, 1863, p. 3, HALL, 1864, p. 52; MCCHESNEY, 1865, pl. 5, fig. 9a-b, pl. 11, fig. 1; 1868, p. 17, pl. 5, fig. 9a-b, pl. 11, fig. 1, p. 18, figs. ——— MEEK & WORTHEN, 1869, p. 155, 156, 159. ——— HALL, 1872, pl. 3A, fig. 13-17, 24-25; Pl. 4, fig. 6. ——— MEEK & WORTHEN, 1873, p. 342, 345, 353. ——— WHITE, 1875, p. 82. ——— HALL & WHITFIELD, 1875, p. 162, pl. 11, fig. 11. ——— WACHSMUTH & SPRINGER, 1881, p. 143 (317). ——— MILLER, 1889, p. 218, 219. ——— WACHSMUTH & SPRINGER, 1890, p. 163, 165, 168. ——— MILLER, 1892b, p. 35. ——— WHITFIELD, 1893, p. 5, 6, 10. ——— KEYES, 1894, p. 189. ——— MILLER, 1894, p. 289. ——— MILLER & GURLEY, 1896a, p. 8, pl. 3, fig. 1-2. ——— WACHSMUTH & SPRINGER, 1897, p. 572-575. ——— MILLER, 1897, p. 731, 732.

Cactocrinus WACHSMUTH & SPRINGER, 1897 (*pars*), p. 601, 606, 608, 609, 611, 612, 618, 619, 621, 622, 624, 625. ——— ROWLEY, 1906, p. 31, pl. 6, fig. 14. ——— LAUDON, 1933, p. 51. ——— LAUDON & BEANE, 1937, p. 247. ——— MOORE & LAUDON, 1943, p. 93, pl. 10, fig. 2; 1944, p. 191-193; pl. 77, figs. 2, 4, 8, 10.

Strotocrinus MEEK & WORTHEN, 1869 (*pars*), p. 160; 1873, p. 349. ——— MILLER & GURLEY, 1895b, p. 48. ——— MILLER, 1889, p. 284; 1897, p. 753.

Type species.—*Actinocrinus nodobrachiatus* WACHSMUTH & SPRINGER.

Generic diagnosis.—Actinocrinitids having a steeply conical dorsal cup and low-arched to conical tegmen with strong centrally located anal tube. The thirty *Amb* tracts, fewer in some or more numerous, divide according to the typical actinocrinitid plan. The upper part of the rays is not protuberant on most species but on some it is slightly protuberant. The rays are separated by interradial plates which in most forms connect openly with the plates of the tegmen. A few advanced species have adjacent rays in contact laterally.

Description.—Actinocrinitids with moderate to steeply conical dorsal cup and low-arched to conical tegmen. The proximal surfaces of the *BB* commonly are folded inward, forming a moderately large surface for the attachment of the column. In some species, the *BB* are broadly folded and relatively smooth, but in other species (Pl. 2, fig. *1d, 2d*) the folded proximal edge of the *BB* is produced into a moderate or strong flange. The *RR* are longer than wide. The $IBrr_1$ are hexagonal and wider than long. The $IBrr_2$ are axillary, pentagonal, and wider than long. The $IIBrr_2$ are axillary, pentagonal, and wider than long. Each $IIBrr_1$ supports an arm on the outside of each ray and an $AxIIIBrr_1$ on the inside of each ray. In primitive species, the $AxIIIBrr_2$ bear two unbranched biserial arms, as in *C. nodobrachiatus*. The plan of division represented in the cusacrinid ray is fundamental and of generic importance; this plan is considered to be typically actinocrinitid (Pl. 2, fig. *1a, 2a;* Pl. 4, fig. *2, 3*). Most of these forms have six unbranched biserial arms in each ray. Some more advanced species (such as *C. asperrimus*) have as many as eight arms to each ray. The additional arms were added in these forms according to a definite plan. Although the $AxIIIBrr_1$ support two unbranched arms in forms with six arms to each ray, the forms with eight arms to each ray have $AxIVBrr_1$ supported toward the outside of the ray on the $AxIIIBrr_1$, and an unbranched biserial arm supported by the $AxIIIBrr_1$ toward the inside of the ray. The $AxIVBrr_1$ in these species support two biserial unbranched arms. Some species of Cusacrinus (for example, *C. arnoldi*) have the rays reduced so that specimens may have only five arms to each ray. This reduction is accomplished by the loss of one or more $AxIIIBrr_1$. The number of arms present on specimens is correlated to ramifications of each ray before it leaves the dorsal cup, because the biserial arms do not bifurcate. The loose muscular articulation between terminal plates of the calical portion of the ray and the proximal *Brr* of the arm is not distinct because of the way in which the lower parts of the arms in most species are welded to the dorsal cup (Pl. 2, fig. *1a-d*). The plates of the ray above the *IIBrr* are deflected outward in many species and the arms bend upward a short distance beyond the cup. The structure of the cup of some species, which have a flangelike extension at arm level, is similar to that of *Teleiocrinus*. In some species, the distal part of the cup is not deflected outward and the arms represent a distal extension of the conical cup.

The calical part of each ray is separated from adjacent rays by interradial plates which extend between the rays into the tegmen; the arms are grouped but not produced into tubular extensions. In some species, the interradial space at arm level is much reduced and the lateral plates of adjacent rays are nearly joined (Pl. 3, fig. *2a,b*). In other species the rays are widely separated at arm level, as in *C. chloris* (HALL) (Pl. 3, fig. *1a-c*). The size and arrangement of interray plates vary from species to species. In most species a single *iIIIBr* is present in the middle of each ray and rests on the interior distal surfaces of the *AxIIBrr*.

The plates of the tegmen in most species are numerous and irregularly polygonal. Many of these plates have long slender spines. The so-called "orals" or "radial dome" plates are not recognizable. In some species, the tegmen is gently arched and the small slender anal tube arising from the center of the tegmen is well differentiated. The tegmen is conical and grades imperceptibly into the anal tube in some species. The variations in shape and ornamentation of the tegmen and tegminal plates are of infrageneric value. The anal tube rises to or beyond the distal extension of the arms.

The unbranched biserial arms of most species extend to a level equal to three or four times the height of the dorsal cup. In many species the arms project laterally from the dorsal cup and curve abruptly upward a short distance from the cup. The visible portion of each arm is fairly straight. The arms extend distally for some distance and then curl inward very sharply and descend to near the surface of the tegmen (Pl. 5, fig. *1a-c, 2a,b*). It seems possible that the distal half of the arm lacked an ambulacral tract and served as a support for the distal ends of the pinnules. The peculiar

development of the distal half of the arms varies from species to species. The structure is well developed in *C. nodobrachiatus* (WACHSMUTH & SPRINGER, 1897, pl. 57, fig. 1) but seems to be weakly developed in *C. daphne* HALL (WACHSMUTH & SPRINGER, 1897, pl. 56, fig. 1). However, it is a structure common to most species of *Cusacrinus*. The *Brr* of the arms are commonly ornamented by nodes, spines, or small ridges.

The pinnules are long, closely packed, and contiguous: they are composed of short joints which have short spines. In many species these pinnular spines project over the pinnulars of the distally adjacent pinnule and form a more or less rigid screen of pinnulars. The proximal half of each arm supports these pinnules, which seem to be fitted into a nonfunctional ambulacral groove on the inside of the infolded distal portion of the arm, the whole making, it is believed, a strong paddle-like arm, which was relatively immobile except at the very

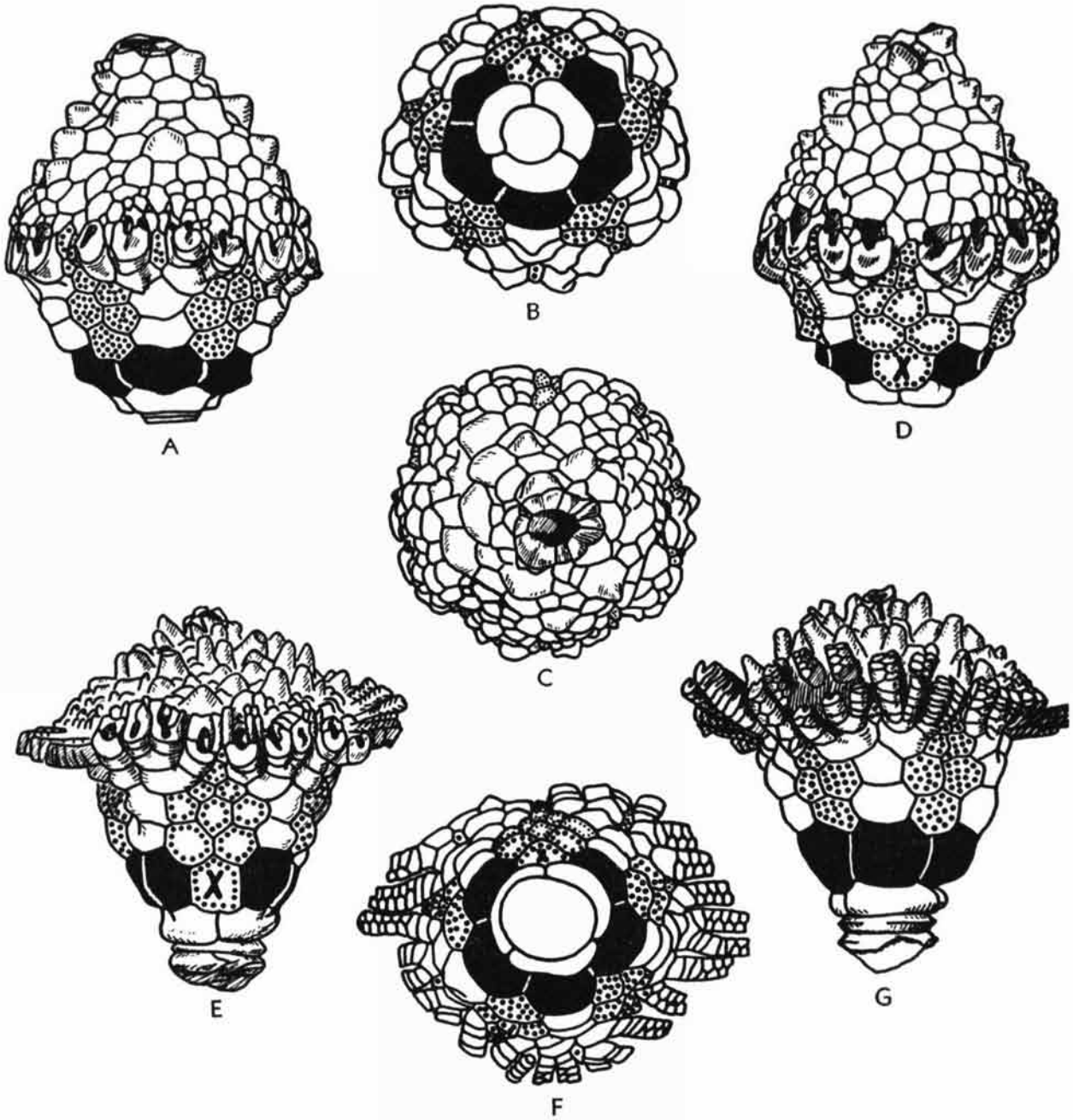


FIGURE 3. Diagrams showing form and structure of *Nunnacrinus mammillatus* (*A-D*), type species of *Nunnacrinus*, from the Lake Valley formation, Lake Valley, N. Mex. (USNM Springer Coll., no. 114,695); and *Cusacrinus nodobrachiatus* (*E-G*), type species of *Cusacrinus*, from the Hampton formation, Le Grand, Iowa (USNM Springer Coll., no. S4,605). *A, G*, anterior views, calyx upright. *B, F*, Basal views. *C*, Top view. *D, E*, Posterior interradial area. All figures ×2.

base of the arm (Pl. 5, fig. *1a, 2a,b*). The degree to which the arms and pinnules are formed into these paddle-like structures varies from species to species.

The column is relatively large in proportion to size of the calyx and composed in most species of a series of well-differentiated nodals and internodals. Although many cusacrinids are preserved with columnals attached, the columnals of this group have never been the object of special study. It is believed that the characters of the columns in general are of infrageneric value.

Remarks.—*Cusacrinus* is one of the most common of the Lower Mississippian crinoids, but great variation within the group has long prevented proper recognition of the genus. The several divergent phyletic trends within the genus indicate relations between it and *Cactocrinus, Nunnacrinus, Actinocrinites, Physetocrinus, Strotocrinus* and *Teleiocrinus*. Therefore, it is not surprising that species of *Cusacrinus* have been assigned to several different genera. Many species of *Cusacrinus* originally were referred to *Cactocrinus* or *Actinocrinites*. SPRINGER evidently was not satisfied with classification of these forms because in unpublished notes he made remarks on the number of arms in various species, which indicates that he had the problem under study.

Many species of *Cusacrinus* have a reduced number of arms to each ray so that the structure of the ray diverges from normal toward that of *Cactocrinus*. Many other species have more than the normal six arms and their structure diverges from normal toward that of *Teleiocrinus*. The relations between some species of *Cusacrinus* (formerly *Cactocrinus* in part) and species of *Teleiocrinus* have been discussed by WACHSMUTH & SPRINGER (1897, p. 626) and WOOD (1914, p. 16). One of the cusacrinid stocks can be traced phylogenetically to *Teleiocrinus* and some species must be placed arbitrarily in one genus or the other. *Teleiocrinus* differs from *Cusacrinus* in having the distal plates of the calical portion of the ray in lateral contact all around the calyx except at the posterior side and in showing a distinct flangelike projection of the calyx at the level of the arms. Although both *Actinocrinites* and *Cusacrinus* have grouped arms and a similar ray pattern, *Cusacrinus* lacks the more or less protuberant ray at the base of the arms which characterizes most species of *Actinocrinites*. Primitive species of *Actinocrinites* are similar to some cusacrinids and it is not always easy to make generic assignment of such forms. The difference between the two groups is accentuated through time by divergent trends, and advanced forms of *Actinocrinites* can be recognized readily as distinct from *Cusacrinus*. *Cusacrinus* differs from *Physetocrinus* and *Strotocrinus* in having an anal tube. The peculiar development of the ray into trunklike projections distinguishes *Steganocrinus* and *Cytidocrinus* from *Cusacrinus*.

Distribution.—Species referred to *Cusacrinus* are known from strata which range from late Kinderhook to middle Osage in age. The oldest known species occur in the Hampton formation of Iowa. *Cusacrinus arnoldi, C. nodobrachiatus*, and *C. ornatissimus* are abundantly represented in crinoid colonies found in the lower ledges of the Maynes Creek member of the Hampton formation at Le Grand, Iowa (LAUDON & BEANE, 1937; LAUDON, 1931). The cusacrinids are mainly confined to the *Cactocrinus* zone and the overlying *Spiriferina* zone of the Maynes Creek (LAUDON, 1931, pp. 428-429). They are not reported from Kinderhook strata below the Maynes Creek member of the Hampton formation. *Cusacrinus imperator* is described from the Gilmore City formation of Iowa and a very similar form is reported from the uppermost portion of the Le Grand beds (LAUDON, 1933, pp. 51-52).

Cusacrinids are not known from the Chouteau limestone, Fern Glen formation, or Reeds Spring limestone of Missouri. Actinocrinitids from the Chouteau are mostly from the lower part and *Cusacrinus* is not represented. Crinoids are known from the Sedalia dolomite (MOORE, 1928, p. 155) but cusacrinids do not seem to be represented. Crinoids from the Fern Glen formation are different from those found in the Chouteau limestone, Hampton formation, and Gilmore City formation. Collections from the Fern Glen do not contain species of *Cusacrinus*.

Cusacrinus is represented in the lower Burlington limestone by numerous species but none are known from the upper Burlington limestone. Species of *Cusacrinus* have not been reported from strata younger than lower Burlington.

Species of *Cusacrinus* are known from Iowa, Missouri, and Ohio. Several species of actinocrinitids from the Mountain limestone of Ireland seem to belong to this genus.

Among previously described crinoids, only such species as can be identified on the basis of original description and illustration are referred by me to *Cusacrinus*. Numerous species that may belong here are retained in other genera to which they are currently referred because of inadequate information concerning identity of the species.

HALL described numerous crinoids from the Burlington limestone of Burlington, Iowa, which were from the collections of C. A. WHITE, W. H. HARRIS, O. THIEME, B. J. HALL, and E. O. HOVEY (1861b, p. 10; 1861c). The types of many of these species have never been illustrated. In June, 1913, SPRINGER received type specimens of some of these species as a part of the C. A. WHITE collection through exchange with the University of Michigan. These specimens are in the Springer Collection, U. S. National Museum. Species of HALL that can be identified as cusacrinids from these types in the Springer Collection are included in the genus *Cusacrinus* and discussed below. Photographs of these unfigured types are presented in this paper.

Opportunity has not been afforded to me for examining the types of all species referred to this genus and, consequently, I have not followed the synonymies given by previous writers. Careful re-

study of types of all species is needed before proper synonymies can be established. Numerous subjective synonymies of earlier workers seem unjustified in the light of published information; therefore, some names long buried in synonymies are exhumed.

Cusacrinus arnoldi (WACHSMUTH & SPRINGER) BOWSHER, n. comb.

Actinocrinus arnoldi WACHSMUTH & SPRINGER, MILLER, 1889, p. 218, fig. 232. ——— WACHSMUTH & SPRINGER, 1890, p. 168, pl. 17, fig. 10.
Cactocrinus arnoldi (WACHSMUTH & SPRINGER) WACHSMUTH & SPRINGER, 1897, p. 622-623, pl. 57, fig. 4a, b. ——— WELLER, 1898, p. 153. ——— LAUDON & BEANE, 1937, p. 248-249, pl. 16, fig. 3-4. ——— BASSLER & MOODEY, 1943, p. 340.

Occurrence.—Hampton formation, Le Grand, Iowa.

Types.—Collection of Delos Arnold, Stanford University.

Cusacrinus asperrimus (MEEK & WORTHEN) BOWSHER, n. comb.

Strotocrinus? asperrimus MEEK & WORTHEN, 1869, p. 160; 1873, p. 349, pl. 8, fig. 3.
Actinocrinus asperrimus (MEEK & WORTHEN) WACHSMUTH & SPRINGER, 1881, p. 142; 1897, p. 575, pl. 60, fig. 5-6. ——— WELLER, 1898, p. 56. ——— BASSLER & MOODEY, 1943, p. 267.

Occurrence.—Burlington limestone, Quincy, Ill.

Type.—Illinois State Collection, Springfield, Ill.

Cusacrinus bischoffi (MILLER & GURLEY) BOWSHER, n. comb.

Actinocrinus bischoffi MILLER & GURLEY, 1896c, p. 8, pl. 3, fig. 1, 2. ——— WELLER, 1898, p. 56. ——— BASSLER & MOODEY, 1943, p. 267.

Occurrence.—Burlington limestone, Burlington, Iowa.

Type.—Collection of Prof. Martin Bischoff, Buffalo, N. Y.

Cusacrinus chloris (HALL) BOWSHER, n. comb.

Plate 3, figures *1a-c*

Actinocrinus chloris HALL, 1861a; 1861b, p. 3; 1861c, p. 275. ——— KIRK, 1943, p. 346.
Actinocrinus tenuisculptus MCCHESNEY, WACHSMUTH & SPRINGER, 1897, p. 571, pl. 55, fig. 4a, b. ——— WELLER, 1898, p. 64. ——— KEYES, 1894, p. 187.
Actinocrinites tenuisculptus (MCCHESNEY) BASSLER & MOODEY, 1943, p. 275. ——— MOORE & LAUDON, 1943, pl. 10, fig. 11; 1944, p. 193, pl. 77, fig. 14.

The types of *Actinocrinus chloris* HALL are three specimens in the Springer collection in the U. S. National Museum, numbered S1,142, S4,630, and S4,631. HALL's original descriptions (1861a; 1861b, p. 3; 1861c, p. 275) are lengthy and are not republished here, although a description of the species is given below. WACHSMUTH & SPRINGER (1897, p. 571, pl. 55, fig. 4a, b) identified this interesting species as *Actinocrinus tenuisculptus* MCCHESNEY. KIRK (1943, p. 346) discussed the identification of *A. chloris.*

Diagnosis.—Cusacrinids having the dorsal cup slightly bowl-shaped, and the tegmen steeply conical, with a centrally located strong anal tube. The arms are grouped but not protuberant and the rays widely separated, with interradial plates openly connected to the plates of the tegmen. Plates of the cup are strongly ornamented by compound radiating ridges.

Description.—The dorsal cup is conical to slightly bowl-shaped, and the tegmen is steeply conical. Although the calyx of the lectotype is slightly mashed, the dorsal cup seems to be approximately 13.5 mm high and 22 mm in diameter. One of the paratypes is smaller and one larger than the lectotype. The proximal margins of the *BB* are directed horizontally into a spinose flangelike process and strongly ornamented by several sharp ridges which extend to the *RR* (Pl. 3, fig. *1a*). *RR* considerably wider than long, ornamented by numerous sharply defined radiating ridges. $IBrr_1$ wider than long, quadrangular in two of the exposed rays and pentagonal and axillary in the other exposed ray of the lectotype. The $IBrr_1$ are quadrangular, wider than long, on the two paratypes. $IBrr_2$ pentagonal, axillary and wider than long. *IBrr* have a strong median ray ridge and radiating ridges. $IBrr_1$ are axillary, wider than long and have a strong median ray ridge. The $IIBrr_1$ on the outside of each ray bear single arms and the $IIIBrr_1$ on the inside of each ray are axillary, each bearing two arms. The arms are thought to be biserial and unbranched. The ray pattern is typically actinocrinitid, except for the quadrangular $IBrr_1$ (Pl. 3, fig. *1a*). The rays are widely separated by a double row of interradial plates: the interradial plates openly connect with the tegmen. The ray just below the base of the arms is slightly protuberant but not so strongly as in *Actinocrinites* (*s. s.*)

The tegmen is conical and composed of numerous irregularly polygonal plates; some bear small but prominent spines.

Remarks.—The delicate ornamentation of the plates, the prominent median ray ridge and the quadrangular $IBrr_1$ distinguish this from all other species of *Cusacrinus.* The structural characteristics of this species are similar to those of *Cusacrinus limabrachiatus* and *C. viaticus.*

Occurrence.—Lower Burlington limestone, Burlington, Iowa.

Types.—A lot of three specimens from the C. A. White collection, formerly cataloged as S1,142 in the Springer collection, are identified by a label as "Types of *A. chloris.*" One of the specimens (Pl. 3, fig. *1a*) is retained under the catalog number S1,142 and designated herein as the lectotype. The remaining two specimens here designated as paratypes (Pl. 3, fig. *1b,c*) are recataloged as S4,630 and S4,631.

Cusacrinus coelatus (HALL) BOWSHER, n. comb.

Actinocrinus coelatus HALL, 1859, p. 585-587, pl. 10, fig. 14a,b; 1860, pl. 2, fig. 1. ——— KEYES, 1894, p. 187. ——— MILLER, 1889, p. 217.

Cactocrinus coelatus (HALL) WACHSMUTH & SPRINGER, 1897, p. 618-619, pl. 59, fig. 8, 9. ——— WELLER, 1898, p. 153. ——— BASSLER & MOODEY, 1943, p. 341.

Occurrence.—Burlington limestone, Burlington, Iowa.

Types.—Worthen collection, Illinois State collection, Springfield, Ill.

Cusacrinus daphne (HALL) BOWSHER, n. comb.

Actinocrinus daphne HALL, 1863, p. 3; 1864, p. 52. ——— HALL & WHITFIELD, 1875, p. 162, pl. 11, fig. 11. ——— MILLER, 1889, p. 217. ——— WACHSMUTH & SPRINGER, 1897, p. 574, pl. 56, fig. 1. ——— WELLER, 1898, p. 57.
Actinocrinites daphne (HALL) BASSLER & MOODEY, 1943, p. 269.

Occurrence.—Waverly sandstone group, Richfield, Summit Co., Ohio.

Types.—New York State Museum, Albany, N. Y.

Cusacrinus denticulatus (WACHSMUTH & SPRINGER) BOWSHER, n. comb.

Cactocrinus denticulatus WACHSMUTH & SPRINGER, 1897, p. 606, pl. 57, fig. 5a,b. ——— WELLER, 1898, p. 153. ——— BASSLER & MOODEY, 1943, p. 341.

Occurrence.—Lower Burlington limestone, Burlington, Iowa.

Holotype.—S1,200, Springer collection, U. S. National Musuem.

Cusacrinus ectypus (MEEK & WORTHEN) BOWSHER, n. comb.

Strotocrinus ectypus MEEK & WORTHEN, 1869, p. 159; 1873, p. 353, pl. 7, fig. 5.
Cactocrinus ectypus (MEEK & WORTHEN) WACHSMUTH & SPRINGER, 1897, p. 611, pl. 56, fig. 10. ——— WELLER, 1898, p. 153. ——— BASSLER & MOODEY, 1943, p. 341.

Occurrence.—Lower Burlington limestone, Burlington, Iowa.

Holotype.—Wachsmuth collection, Harvard Coll. Museum of Comparative Zoology, Cambridge, Mass.

Cusacrinus elephantinus (AUSTIN & AUSTIN) BOWSHER, n. comb.

Actinocrinites elephantinus AUSTIN & AUSTIN, 1842, p. 109; 1843, p. 200. ——— WRIGHT, 1943, p. 231-234, pl. 8, figs. 1-3.

Occurrence.—Lower Carboniferous, Hooks Head, Ireland.

Type.—Whereabouts unknown.

Cusacrinus gracilis (WACHSMUTH & SPRINGER) BOWSHER, n. comb.

Actinocrinus gracilis WACHSMUTH & SPRINGER, 1897, p. 572-573, pl. 56, fig. 11. ——— WELLER, 1898, p. 58. ——— BASSLER & MOODEY, 1943, p. 270.

Occurrence.—Lower Burlington limestone, Burlington, Iowa.

Types.—Unknown number of specimens in Harvard Coll. Museum of Comparative Zoology, Cambridge, Mass., and six specimens (S1,130) in the Springer collection, U. S. National Museum.

Cusacrinus hurdianus (MCCHESNEY) BOWSHER, n. comb.

Actinocrinus hurdianus MCCHESNEY, 1860, p. 24; 1865, pl. 5, figs. 9a,b; pl. 11, fig. 1; 1868, p. 17, pl. 5, fig. 9a,b, p. 18, text fig.
Cactocrinus hurdianus (MCCHESNEY), 1860, WACHSMUTH & SPRINGER, 1897, p. 601. ——— WELLER, 1898, p. 59. ——— BASSLER & MOODEY, 1943, p. 342.

Occurrence.—Lower(?) Burlington limestone, Burlington, Iowa.

Types.—Presumably lost in the Chicago fire (WACHSMUTH & SPRINGER, 1897, p. 601).

EXPLANATION OF PLATE 3

1a

1b

1c

2a

2b

4a

3

4b

4c

4d

5a

5b

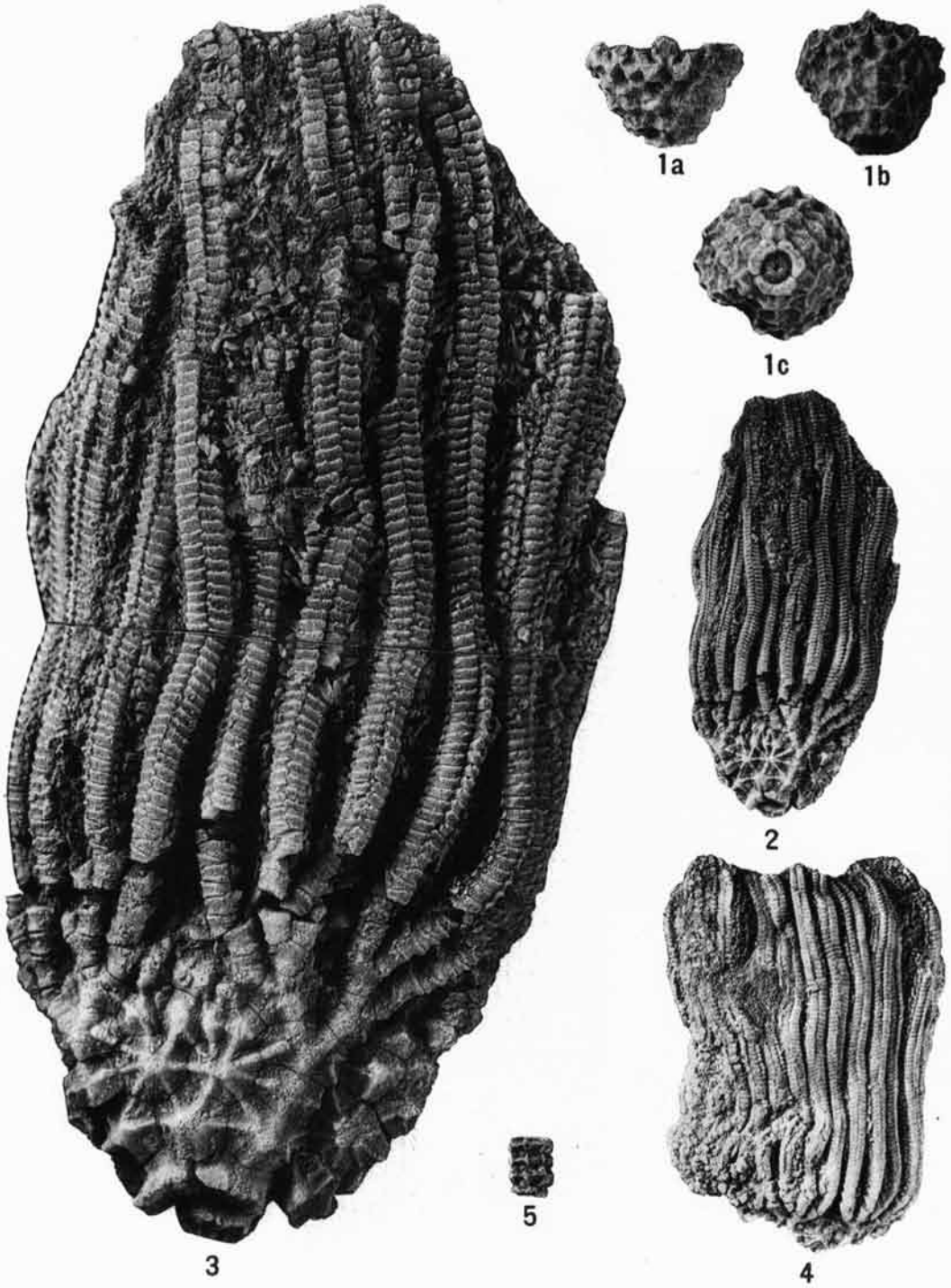
5c

6a

7b

7a

6b



BOWSHER — Mississippian Camerate Crinoids

Cusacrinus imperator (LAUDON) BOWSHER, n. comb.

Cactocrinus imperator LAUDON, 1933, p. 51-52, pl. 2, fig. 9; pl. 3, fig. 1. ——— BASSLER & MOODEY, 1943, p. 342.

Occurrence.—Gilmore City formation, Gilmore City, Iowa.

Types.—The holotype, 2,074, and paratype, 2,077, State University of Iowa, Iowa City, Iowa.

Cusacrinus limabrachiatus (HALL) BOWSHER, n. comb.

Plate 4, figures 2-4

Actinocrinus limabrachiatus HALL, 1861a, p. 2; 1861b, p. 2; 1861c, p. 268. ——— WACHSMUTH & SPRINGER, 1881, p. 144. ——— MILLER, 1889, p. 218. ——— WHITFIELD, 1893, p. 5, pl. 1, figs. 8-9.

Cactocrinus limabrachiatus (HALL) WACHSMUTH & SPRINGER, 1897, p. 608-609, pl. 58, fig. 10a,b (probably not fig. 9). ——— WELLER, 1898, p. 154. ——— BASSLER & MOODEY, 1943, p. 342.

HALL (1861a; 1861b, p. 2) first gave a brief description of the species and then (HALL, 1861c, p. 268-269) he described the type in detail and discussed fragments of other specimens. WHITFIELD (1893, p. 5) republished HALL's description of 1861c. WACHSMUTH & SPRINGER (1897, p. 608-609) gave a very good description of this species. It seems inadvisable to quote any of these discussions and I present below only such remarks as are necessary to characterize the species.

Diagnosis.—The most distinctive features of this species are the strongly ornamented plates of the cup, the splayed character of the ray at the base of the arms, the cuneiform *Brr* at the base of the arms, the peculiar ornamentation of the *Brr* of the arms, and the strong transverse ridges on *Brr* of the arms.

Description.—The proximal folded margin of the *BB* is extended into a prominent flange. The *BB* are somewhat excavated for reception of the column. All plates of the cup are marked by simple strong radiating ridges and a strong median ray ridge occurs. Compound ridges extend from *BB* to *RR*. The center of each interradial plate is developed into a sharp but short spine.

The proximal plates of the posterior interradial area are large and followed by numerous small plates, all highly ornamented with ridges and spines. The proximal interradial plates are large and by comparison the $IBrr_1$ are small and quadrangular. The interradial areas are openly connected with the tegmen and the rays are well separated.

The ray at arm level is broadly spread out as an extension of the conical cup but not produced into an outwardly projecting trunk as in *Actinocrinites*. The *iIIIBrr*, which lie within the ray, separate each ray into two distinct parts and connect openly with the plates of the tegmen (Pl. 4, fig. 2-4).

The proximal four or five *Brr* of each arm are long and cuneiform, the remainder of each arm being distinctly biserial. The *Brr* in the biserial portion of the arms are marked close to their distal margins by a sharp conspicuous transverse ridge and the surface of the lower parts of the *Brr* are beautifully hispidate. This same type of finely hispidate surface is common to all plates in the dorsal cup. The arms are narrow and rounded at the base but become trapezoidal in the outer part where the transverse ridges of the *Brr* become subspinose (Pl. 4, fig. 3). The species has 30 arms.

The pinnules are long, have a hispidate surface, and long slender slightly curved pinnular hooks.

Remarks.—HALL (1861c, p. 269) compared this species with *Actinocrinites spinotentaculus*, but because adequate description and illustrations of types of *A. spinotentaculus* are not available, satisfactory comparison cannot be made between the two species. *Cusacrinus limabrachiatus* most closely resembles *C. gracilis*, *C. penicillus*, and *C. tuberculosus*. It differs markedly from *C. gracilis* and *C. penicillus*, which have fewer interradial plates, nodose plates without angular radiating ridges, and lack the transverse ridges on *Brr* of the arms, although the general shape and arrangement of plates of the cup and character of *Brr* of the arms is similar in the three species. *C. viaticus* is of the same general type as these species but the holotype and only known specimen is too poorly preserved for comparison with *C. limabrachiatus*. *C. tuberculosus* is very similar to *C. limabrachiatus* but differs from it in having tuberculate markings on the plates of the cup and in having lateral spines

EXPLANATION OF PLATE 4

on the *Brr*. The *Brr* of the arms of *C. tuberculosus* bear weak transverse ridges which are similar to those on *Brr* of *C. limabrachiatus*. A specimen of *Cusacrinus* (S4,607) in the Springer collection, U. S. National Museum, identified as *A.* sp. cf. *A. polydactylus* from the Mountain limestone at Waterford, Ireland, is similar to *C. limabrachiatus* but has fewer plates in the interradial areas, angular smooth plates in the cup, and prominent nodes on the lateral margins of *Brr* of the arms. This form lacks the transverse ridges on the *Brr* which are so conspicuous on *C. limabrachiatus*. It seems likely that this species from Ireland is new and not properly identified with *A. polydactylus*.

Occurrence.—(Lower?) Burlington limestone, Burlington, Iowa.

Types.—HALL (1861c, p. 268) states that the specimens described are from the collection of C. A. WHITE. A lot of three specimens, S1,207, in the Springer collection is labelled as follows: "*Cactocrinus limabrachiatus*, HALL. (*Actinoc. dodo* Burl. Lim., Burlington, Ia. White col. (TYPES) Not figd." One of these specimens (Pl. 4, fig. 2,3) is here selected as the lectotype of *Actinocrinus limabrachiatus* HALL and retained under the catalog no. S1,207. Another specimen (Pl. 4, fig. 4) is here selected as a paratype and is recataloged as S4,625. A third specimen in the type lot (Pl. 4, fig. 5) is a fragment of a teleiocrinid columnal. This fragment is removed from the type lot and cataloged as *Teleiocrinus* sp. indet (S4,626).

Cusacrinus longus (MEEK & WORTHEN) BOWSHER, n. comb.

Actinocrinus longus MEEK & WORTHEN, 1869, p. 156; 1873, p. 345, pl. 8, fig. 1a,b ——— WACHSMUTH & SPRINGER, 1881, p. 144. ——— MILLER, 1889, p. 218.
Cactocrinus longus (MEEK & WORTHEN) WACHSMUTH & SPRINGER, 1897, p. 609-610, pl. 57, fig. 8. ——— WELLER, 1898, p. 155. ——— BASSLER & MOODEY, 1943, p. 342.

Occurrence.—Burlington limestone (lower beds), Burlington, Iowa.

Types.—Harvard Coll. Museum of Comparative Zoology, Cambridge, Mass.

Cusacrinus nodobrachiatus (WACHSMUTH & SPRINGER) BOWSHER, n. comb.

Plate 2, figures *1a-d*, *2a-d*, text figures 3A-C

Actinocrinus nodobrachiatus WACHSMUTH & SPRINGER (misspelled *novobrachiatus in* MILLER, 1889, p. 218). ——— WACHSMUTH & SPRINGER, 1890, p. 165, pl. 15, fig. 5; pl. 16, fig. 10.
Cactocrinus nodobrachiatus (WACHSMUTH & SPRINGER) WACHSMUTH & SPRINGER, 1897, p. 622, pl. 57, fig. 1, 2. ——— WELLER, 1898, p. 155. ——— ROWLEY, 1906, p. 31, pl. 6, fig. 14. ——— LAUDON & BEANE, 1937, p. 247, pl. 16, fig. 2. ——— BASSLER & MOODEY, 1943, p. 343.

Diagnosis.—Cusacrinids with conical to bowl-shaped dorsal cup and low arched spinose tegmen with a centrally located small slender anal tube. Plates of the cup thick and tumid, with sutures deeply indented. Almost all specimens have six arms in each ray. Cup extended outwardly at arm level, arms turning abruptly upward a short distance away from the cup. Arms curl abruptly inward and descend to the level of the tegmen. *Brr* of the arms bear prominent spikes or short blunt spines. Pinnulars with short thick hooks which overlap pinnulars of distally adjacent pinnule.

Description.—The over-all height of the lectotype to the base of the anal tube is approximately 19.5 mm. The height to the level of the *Amb* openings is 12.3 mm and to base of the arms 11.5 mm. The diameter of the dorsal cup at the base is approximately 7.6 mm and just below arm level, excluding the expanded flange at arm level, it is approximately 16.4 mm. The tegmen is arched approximately 5.6 mm above the top of the *Amb* openings. The arms, which extend 2 to 4 mm outward from the cup before turning upward, are approximately 1.7 mm wide at the base (Pl. 2, fig. *1a-d;* Pl. 5, fig. *1a*, *2a,b*).

The ornamentation of plates is relatively simple, with faint narrow ridges radiating from the center of most. These ridges are more distinct on the *RR* but tend to fade out in the upper part of the cup. A median ray ridge is faintly developed.

The *BB* are short and bear thick rounded transverse ridges. Faint ridges run from *BB* to *RR*, which are as wide as high and ornamented by moderately strong rounded radiating ribs. The $IBrr_1$ are wider than long and hexagonal. The $AxIBrr_2$ are pentagonal and wider than long. The axillary $IIBrr_1$ support biserial unbranched arms toward the lateral margin of the rays and $AxIIIBrr_1$ toward the inside of the rays. The $AxIIIBrr_1$ support two biserial unbranched arms. There are six arms to each ray; the lectotype had 30 arms in all. The *iIIIBr* which lies in the middle of each ray rests on a part of the distal surface of the $AxIIBrr_1$ and separates each ray into two equal parts (Pl. 2, fig. *1a*). Plates of the ray above the *RR* are tumid and show only faint radiating ribs. The rays are separated at arm level by interradial plates.

The interradial plates are regularly polygonal, tumid, and show only faint radiating ribs. Five relatively large plates occur between each ray. These are followed by two elongate tumid plates which separate adjacent rays and connect openly with the plates of the tegmen (Pl. 2, fig. *1a*).

The plates of the posterior interray area are $X + 2 + 3 + 2 + 1$. These are followed by a single row of tumid plates which connect to the tegmen. The sculpture of these plates is the same as on other plates of the dorsal cup.

The tegmen is composed of numerous small slightly tumid plates which surround numerous larger plates having prominent spines. The spines on the lectotype are approximately 1.5 mm in diameter at the base and taper slightly to blunt rounded tips. The spines are approximately 4 mm in height. The tegmen is very slightly depressed in the *iamb* areas. The anal tube of the lectotype is located centrally, small (2.8 mm in diameter), slender, and composed of small spinose plates. The anal tube is missing from the lectotype but probably extended upward more than 35 or 40 mm.

The arms are broad and biserial at their origin (Pl. 2, fig. *1a;* Pl. 5, fig. *1a*).

Several columnals remain on the lectotype. These indicate that the column is composed of an alternating series of nodals and internodals. The diameter of the nodals is approximately 6 mm. The nodals are disc-shaped, with angular to rounded edges.

Remarks.—LAUDON AND BEANE (1937, p. 248) stated that: "*Cactocrinus nodobrachiatus* as originally described and figured is typical of a species which occurs abundantly in the Le Grand fauna. The later illustrations used by WACHSMUTH and SPRINGER [17 (1897), pl. LVII, figs. 1, 2] in Crinoidea Camerata are decidedly nontypical of the species. The difficulty probably lies in the illustration of the calyx because arms appear to be those of *C. nodobrachiatus.*" An examination of the specimens which served as the originals from which were prepared the drawings in figs. *1,2* of Crinoidea Camerata (WACHSMUTH & SPRINGER, 1897, pl. 57) demonstrates that these drawings are inaccurate because the artist failed to present the true sculpture of the plates. The ornamentation of plates of these two specimens (Springer collection S1,192) is identical to, although more massive than, that of plates of the lectotype (Pl. 2, figs. *1a-d;* Pl. 5, fig. *1a*). In all aspects these two specimens are more massive than the lectotype but they are typical of the many specimens of this species in the Springer collection, except for several obviously young specimens. Young specimens more closely resemble the lectotype. Therefore, I believe that the lectotype represents a mature but not gerontic specimen, whereas WACHSMUTH & SPRINGER later (1897, pl. 57, fig. 1,2) illustrated gerontic and typical specimens (this paper, Pl. 5, figs. *1a, 2a,b*). The plates of gerontic specimens become very tumid and simply but coarsely ornamented. The difference between the shape of the dorsal cup of the lectotype and the specimen illustrated in pl. 57, fig. 1 of Crinoidea Camerata (WACHSMUTH & SPRINGER, 1897) is shown in text fig. 4. The dorsal cup of the lectotype is steeply conical, whereas those of gerontic specimens are bowl-shaped. The diameter of the *B* circlet in the holotype and gerontic specimens is about the same, 7.3 to 7.9 mm. The *R* circlet of gerontic specimens is much more expanded than that of the lectotype (Fig. 4) and produces a bowl-shaped calyx. The height of the dorsal cup to the level of the arms is about the same in the lectotype and most gerontic specimens but the diameter of the dorsal cup just below the arms of the lectotype (16.4 mm) is less than that of gerontic specimens of comparable height, 17.2 to 18.5+ mm. In order to compare the shape of dorsal cups, I have compared the height of the cup at arm level to the diameter of the cup at arm level minus the diameter of the *B* circlet. This ratio for the lectotype is approximately 0.77 and for 13 other gerontic specimens it ranges from 0.78 to 0.96. The ratio for specimens whose height is about equal to that of the lectotype ranges from 0.78 to 0.92 and averages about 0.86. Although one cannot make accurate measurements of these specimens, the differences in the shape of the cups is obvious and it seems likely that these differences are related to growth stages of the crinoid.

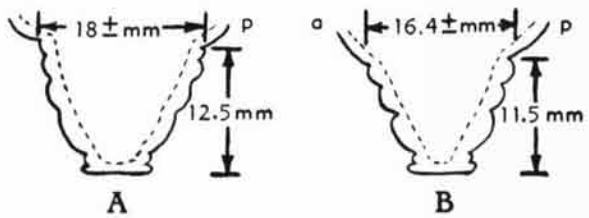


FIGURE 4. Diagrams showing difference in shape of dorsal cup of (A) the lectotype of *Cusacrinus nodobrachiatus* (USNM Springer Coll., no. S4,605) and a gerontic specimen of this species (USNM Springer Coll., no. S1,192), both from the Hampton formation at Le Grand, Iowa. The cup ratio of the lectotype is 18.0-7.9/12.5 = 0.89, whereas that of the gerontic specimen is 16.4-7.6/11.5 = 0.77. Anterior side indicated by *a* and posterior side by *p*.

The arms are missing from the lectotype and the following discussion is based on the specimen (S1,-192) illustrated by WACHSMUTH & SPRINGER (1897, pl. 57, fig. 1) which is considered typical of the species. The arms on this specimen are approximately 2 mm wide, which is slightly wider than those on the lectotype. The arms maintain the same width to their greatest height, approximately 40 mm above the base of the arms, at which point they curl inward abruptly. The *Brr* in the middle part of the arms bear prominent nodes or spines. These are irregularly developed, 6 to 15 or more on each arm. After curling inward, the arms descend along the distal ends of the pinnules nearly to the tegmen (Pl. 5, fig. *1a-c*). This portion of the arms does not bear nodes or spines, is dorsally compressed and seems to lack pinnules.

The pinnules on the above specimen are relatively short, approximately 8 mm long in the middle part of the arm, and they shorten gradually toward the outer part of the arms where the pinnules are only about 2 mm long. The pinnules are composed of long slender pinnulars which are approximately 0.9 mm long near the arms but only about 0.1 mm long near the tip of each pinnule. The first six or seven pinnulars of each pinnule bear stout hooks which overlap onto the outer surface of pinnulars of distally adjacent pinnules. The remainder of the pinnulars of each pinnule become progressively shorter and lack hooks (Pl. 5, fig. *2a,b*). The true function of this peculiar pinnule structure, which *C. nodobrachiatus* shares in common with many other species of actinocrinitids, is unknown.

Occurrence.—Hampton formation (Maynes Creek member), Le Grand, Iowa.

Types.—The specimen which served as the original for the drawing used by WACHSMUTH & SPRINGER (in vol. 8, part 2, Palaeontology of Illinois, Section II, pl. 16, fig. 10, 1890) is here selected as the lectotype of *Actinocrinus nodobrachiatus.* This specimen, along with 47 others and four plaster

casts, was listed as S1,192, Springer collection. The specimen designated as lectotype (Pl. 2, fig. *1a-d*, *2a-d*) has been cataloged separately as S4,605, Springer collection, U. S. National Museum. The specimen illustrated in this same publication (WACHSMUTH & SPRINGER, 1890) in pl. 15, fig. 5, as *Actinocrinus nodobrachiatus* (misspelled *odobrachiatus*) is here selected as a paratype. This specimen, presumably on a slab with other crinoids, is represented in the lot bearing the number S1,192 by four plaster casts. The specimen has not been located. The hypotypes of *C. nodobrachiatus*, formerly included under S1,192, have been removed from the lot and cataloged as S4,633. I have studied in addition 43 specimens in lot S1,192 and 29 specimens in lot S1,193 identified as *Cactocrinus nodobrachiatus* by SPRINGER.

Cusacrinus ornatissimus (WACHSMUTH & SPRINGER) BOWSHER, n. comb.

Actinocrinus ornatissimus WACHSMUTH & SPRINGER, in MILLER, 1889, p. 219. ——— WACHSMUTH & SPRINGER, 1890, p. 163, pl. 16, fig. 9 (not pl. 17, fig. 3). ——— WACHSMUTH & SPRINGER, 1897, p. 621, pl. 57, fig. 3. ——— WELLER, 1898, p. 156. ——— LAUDON & BEANE 1937, p. 247, pl. 16, fig. 5.

Occurrence.—Hampton formation (common in the Maynes Creek member), Le Grand, Iowa. BASSLER & MOODEY (1943, p. 343) report this species also from Spring Canyon, Alden (Alder), Mont. (Madison ls). This occurrence is not substantiated in the literature.

Holotype.—S1,194, Springer collection, U. S. National Museum, Washington, D. C.

Cusacrinus penicillus (MEEK & WORTHEN) BOWSHER, n. comb.

Actinocrinites penicillus MEEK & WORTHEN, 1869, p. 155.
Actinocrinus penicillus (MEEK & WORTHEN), 1873, p. 342-343, pl. 8, fig. 2 * ——— WELLER, 1898, p. 61. ——— BASSLER & MOODEY, 1943, p. 272.

Occurrence.—Lower Burlington limestone, Burlington, Iowa.

Type.—No. 38 of WACHSMUTH'S collection, Harvard Coll. Museum of Comparative Zoology, Cambridge, Mass.

Cusacrinus spinotentaculus (HALL) BOWSHER, n. comb.

Actinocrinus spino-tentaculus HALL, 1860, p. 86-87.
Actinocrinus spinotentaculites HALL, 1872, pl. 3A, fig. 13-17.
Cactocrinus coelatus var. *spinotentaculus* (HALL) WACHSMUTH & SPRINGER, 1897, p. 619, pl. 59, fig. 10. ——— WELLER, 1898, p. 153.

The specimen illustrated by WACHSMUTH & SPRINGER (1897) on pl. 59, fig. 10, seems to be different from the specimen on which HALL (1860, p. 86-87; 1872, pl. 3A, fig. 13) based his description of the species, thereby raising doubt concerning the accuracy of their identification.

Occurrence.—Burlington limestone, Burlington, Iowa.

Type.—Friedrich Leunig collection, University Museum, Göttingen, Germany.

Cusacrinus tenuisculptus (MCCHESNEY) BOWSHER, n. comb.

Actinocrinus tenuisculptus MCCHESNEY, 1860, p. 15; 1865, 1868, p. 11-12, pl. 5, fig. 1a,b, text fig.
Actinocrinites tenuisculptus (MCCHESNEY) BASSLER & MOODEY, 1943, p. 275 (partim).
Cactocrinus tenuisculptus (MCCHESNEY) KIRK, 1943, p. 346.

KIRK (1943, p. 364) discussed the identification of *Actinocrinus chloris* HALL and *Actinocrinus tenuisculptus* MCCHESNEY. The species identified by WACHSMUTH & SPRINGER (1897, p. 57) and MOORE & LAUDON (1943, pl. 10, fig. 11) as *A. tenuisculptus* is in reality HALL's (1861a and 1861b, p. 3) *A. chloris*. *A. tenuisculptus* is herein referred to *Cusacrinus*, because MCCHESNEY's illustrations (1865, pl. 5, fig. 1a,b) are adequate for generic identification.

Occurrence.—Burlington limestone, Columbia, Mo.

Type.—Whereabouts unknown.

Cusacrinus thetis (HALL) BOWSHER, n. comb.

Plate 3, figures *2a,b*, *3*

Actinocrinus thetis HALL, 1861b, p. 11. ——— WHITFIELD, 1893, p. 6, pl. 1, fig. 10.
Cactocrinus thetis (HALL) WACHSMUTH & SPRINGER, 1897, p. 614, pl. 5, fig. 11; pl. 56, fig. 3,4. ——— WELLER, 1898, p. 157. ——— BASSLER & MOODEY, 1943, p. 334.

Two specimens in the Springer collection, U. S. National Museum, S1,228, have the following on an original label: "*Cactocrinus thetis* HALL (*Actinocrinus thetis*, H.) Burlington Lim. Burl. Ia. White Col. (TYPES) not figured."

I am unable to decide whether or not these two specimens are conspecific. One of the specimens (S4,632) shows a portion of the arms but the calyx is missing. The specimen is too poorly preserved to permit accurate comparison with the second one (S1,128), which is a crushed calyx with parts of some arms preserved. This latter specimen is herein selected as lectotype (Pl. 3, fig. *2a,b*). The specimens illustrated by WACHSMUTH & SPRINGER (1897, pl. 56, fig. 3, 4) were incorrectly identified as *C. thetis* (HALL). These crinoids represent a distinctly recognizable species and probably should be given a new specific name; however, because of problems of synonymies existing in this group of crinoids it is not wise to propose a new name at this time.

The specimen illustrated by WHITFIELD (1893, pl. 1, fig. 10) seems to be conspecific with the lectotype of *A. thetis* HALL.

Diagnosis.—Cusacrinids with a truncate conical base in which the *BB* are nearly covered by the column and directed horizontally so as to be almost invisible from the side. The dorsal cup is widely conical and approximately twice as wide as high. The adjacent rays are in contact laterally or separated by a small interradial plate. The plates of the dorsal cup bear strong, distinctive ridges which do not change in strength from the base to arm level.

Description.—Dorsal cup truncate conical, ap-

proximately twice as wide as high. The cup is crushed and accurate measurements are not possible, although the cup is approximately 8.5 mm high. The *BB* are greatly reduced and directed horizontally so as to be almost invisible in side view. The lower half of the surface of *RR* is horizontally directed, almost in the plane of surface of the *BB*. The *RR* turn abruptly upward at the middle of the plates which is marked by a conspicuous transverse rib. On each *R* this rib coalesces with radiating ribs that extend toward adjacent plates. These radiating ribs are prominent on the $IBrr_1$ and develop into strong radiating ridges on the succeeding plates, which also have well-developed central nodes (Pl. 3, fig. *2b*). The cup flares sharply outward at the level of the $IIBrr_1$. The arms are missing from the *rp* ray, and partly from the *ra* and *lp* ray of the lectotype. There are six arms in the *la* ray and five in the anterior ray of the lectotype. There are 26 arms preserved on the paratype (S4,632). The species is believed to have 25 to 30 arms. The arm structure of the *la* and *ant* rays is typically cusacrinid.

The arms are approximately 2.5 mm in width at the base, and become slightly wider in the middle part. The dorsal surface is broadly rounded and seems to lack distinctive ornamentation. Short blunt pinnular hooks occur on the pinnulars. Only a few poorly preserved pinnules are present, so that little can be said as to characters of the pinnules.

The tegmen of the lectotype seems to have been injured, because the anal tube is very short and greatly distended (Pl. 3, fig. *2a*). In this specimen the greatly inflated tegmen and anal tube are composed of numerous, small polygonal plates, very unlike the tegmen and anal tube of most cusacrinids. The anal tube on the specimen illustrated by WHITFIELD (1893, pl. 1, fig. 10) seems to be normal for cusacrinids and is probably characteristic of this species.

Occurrence.—Burlington limestone, Burlington, Iowa.

Type.—Lectotype (here selected) S1,228 (from C. A. White collection), Springer collection, U. S. National Museum, Washington, D. C. One specimen, a cluster of arms without calyx, originally in this lot, herein designated paratype, has been recatalogued as *Cusacrinus thetis*? (HALL), no. S4,632, Springer collection, U. S. National Museum, Washington, D. C.

Cusacrinus tuberculosus (WACHSMUTH & SPRINGER) BOWSHER, n. comb.

Actinocrinus tuberculosus WACHSMUTH & SPRINGER, 1897, p. 573, pl. 52, fig. 8a-c. ——— WELLER, 1898, p. 65.
Actinocrinus tuberculosus (WACHSMUTH & SPRINGER) BASSLER & MOODEY, 1943, p. 276.

Occurrence.—Upper Burlington limestone, Burlington, Iowa.

Holotype.—S1,147, Springer collection, U. S. National Museum, Washington, D. C.

Cusacrinus viaticus (WHITE) BOWSHER, n. comb.

Plate 5, figures 3, 4

Actinocrinus viaticus WHITE, 1874, p. 16. ——— WHITE, 1877, p. 82, pl. 5, fig. 1. ——— WACHSMUTH & SPRINGER, 1897, p. 555. ——— WELLER, 1898, p. 65.
Actinocrinites viaticus (WHITE) BASSLER & MOODEY, 1943, p. 276.

The holotype of this species is a poorly preserved specimen. The dorsal cup is approximately 4.8 mm high and 15.6 mm in diameter; it is low bowl-shaped in outline. The rays are widely separated by interradial plates which are in open contact with the tegmen. The rays are not formed into protuberant arm trunks. Six arms occur in each of the exposed rays, making a total of 30 arms (Pl. 5, fig. *3,4*). The rays are divided by *iIIIBrr* which lie within the ray. The arms are directed laterally from the cup for a distance of approximately 7.5 mm, after which they curve broadly upward.

The holotype is badly weathered and the surface characters of the arms are obliterated. There remain, however, the remnants of relatively sharp-edged, radiating ridges on the plates of the calyx.

The lower *Brr* of the arms are cuneiform, long and slender, but they become biserial a short distance above the base of the arm.

This species most closely resembles *C. tuberculosus* (WACHSMUTH & SPRINGER) and *C. limabrachiatus* but differs from them in having a more bowl-shaped cup, arms directed outward more strongly, and stronger ornamentation of the calyx plates.

Occurrence.—Lower Carboniferous, Mountain Spring, Old Mormon Road, Nevada.

Holotype.—8525, U. S. National Museum, Washington, D. C.

GENUS **NUNNACRINUS** BOWSHER, n. gen.

Actinocrinus (MILLER) HALL, 1861b, p. 15. ——— MILLER, 1881, p. 309, pl. 7, fig. 1, 1a. ——— ROWLEY & HARE, 1891, p. 101, pl. 2, fig. 16. ——— MILLER & GURLEY, 1895b, p. 49, pl. 2, fig. 25, 26; 1896b, p. 26, pl. 1, fig. 25-27; p. 32, pl. 2, fig. 15, 16; 1896c, p. 5, pl. 1, fig. 1, 2; p. 6, pl. 1, figs. 3, 4. ——— MILLER, 1897, p. 731. ——— WELLER, 1898, p. 58, 61, 62; 1909, p. 285, pl. 11, fig. 4, 5.
Actinocrinites MILLER, 1821, BASSLER & MOODEY, 1943, p. 269, 272, 273, 278. ——— MOORE & LAUDON, 1944, p. 193, pl. 78, fig. 2.
Cactocrinus WACHSMUTH & SPRINGER, 1897, p. 601, 605. ——— WELLER, 1898, p. 156.

Type species.—Nunnacrinus mammillatus BOWSHER, new species.

Generic diagnosis.—Actinocrinitids having a conical dorsal cup and conical tegmen with a strong centrally located anal tube. The *Amb* tracts are reduced from the typical actinocrinitid plan to four branches arising isotomously in each ray, total of 20 branches. The rays are separated at arm level by interradial plates which openly connect with the plates of the tegmen. The arms are grouped but most species lack protuberant ray trunks.

Description.—The proximal surfaces of the *BB* commonly are folded inward forming a moderately large surface for attachment of the column. In most species the folded proximal edge of the *BB* is produced into a transverse rib or weak flange. The *RR* are wider than long. The $IBrr_1$ of most species are hexagonal, approximately twice as wide as long. Some advanced species have quadrangular $IBrr_1$. The $IBrr_2$ are axillary, pentagonal and wider than long. The $IIBrr_1$ are hexagonal and wider than long. The arms arise directly from distal surfaces of the $IIIBrr_1$; species of *Nunnacrinus* have only four arms to each ray, or a total of 20 arms (Fig. 3*A-D*). The distal surfaces of the $IIIBrr_1$ have ligamental and muscular fossae and a fulcral ridge. The arms of *Nunnacrinus* are very similar to those of *Cactocrinus*, stout, unbranched, biserial, and bearing pinnules with strong pinnular hooks.

The arrangement of the plates of the calyx in the posterior interray is $X + 2 + 3 + 2 + 2$. The anal plate lies in the *R* circlet and is of the same size as the *RR*. The arrangement of plates in the other interradial areas varies from species to species. Two or more small more or less elongate plates separate adjacent rays and the plates of the interradial areas connect with plates of the tegmen (Pl. 6, fig. 2*a-d*). A small, elongate *iIIIBr* separates each ray into two halves and these small plates are connected to the plates of the tegmen (Pl. 6, fig. 2*a*). Some advanced species lack *iIIIBrr*.

The tegmen, low to steeply conical, is composed of numerous irregularly polygonal plates. In some species there is great variation in size, shape, and ornamentation of these plates, but in others the plates of the tegmen are of similar size, shape, and ornamentation. Many plates of the tegmen are nodose or knobby. The distal part of the tegmen of most species grades insensibly into the nodose or spinose anal tube which extends beyond the distal portions of the arms.

Remarks.—Nunnacrinids differ from cusacrinids in having a more reduced ambulacral system; cusacrinids have 30 terminal *Amb* tracts (arms) whereas nunnacrinids have only 20 such tracts. Nunnacrinids differ from cactocrinids in having rays that are separated by interradial plates of the dorsal cup which connect to the plates of the tegmen, and in having each ray separated into two equal halves by *iIIIBrr*. Nunnacrinids differ from actinocrinitids (s. s.), steganocrinids, and cytidocrinids in having a more reduced *Amb* system and lacking the ray trunks of these types. Nunnacrinids differ from physetocrinids, strotocrinids, and teleiocrinids in having a more reduced *Amb* system and lacking the consolidated girdle of upper cup plates at the base of the arms.

Distribution.—Species referred to *Nunnacrinus* are known in strata ranging from early to medial Osagian in age. Several undescribed species occur in the Sedalia dolomite of Missouri, which is late Kinderhookian in age. Nunnacrinids occur abundantly in the Lake Valley formation of New Mexico and the lower Burlington limestone of the Upper Mississippi River Valley. A single species, *N. rubra* (WELLER), is known from the Fern Glen formation of Missouri. Forms transitional between *Cusacrinus* and *Nunnacrinus* are common in the Lodgepole and Madison limestones of Montana.

Many species of actinocrinitids are referable to *Nunnacrinus* but because of inadequate original descriptions and illustrations, only a few species can be referred to it without doubt.

Nunnacrinus dalayanus (MILLER) BOWSHER, n. comb.

Actinocrinus dalayanus MILLER, 1881, p. 309, pl. 7, fig. 1, 1a; 1889, p. 217.
Cactocrinus proboscidialis (HALL) WACHSMUTH & SPRINGER, 1897, p. 601. ——— WELLER, 1898, p. 156. ——— BASSLER & MOODEY, 1943, p. 343.

Occurrence.—Lake Valley formation, Lake Valley, N. Mex.

Type.—Whereabouts of type or types not known by the writer.

Nunnacrinus foveatus (MILLER & GURLEY) BOWSHER n. comb.

Actinocrinus foveatus MILLER & GURLEY, 1895b, p. 49, pl. 2, fig. 25, 26. ——— MILLER, 1897, p. 731. ——— WELLER, 1898, p. 58.
Actinocrinites foveatus (MILLER & GURLEY) BASSLER & MOODEY, 1943, p. 269.

Occurrence.—Burlington limestone, Sedalia, Mo.

Cotypes.—2228, Miller collection, University of Cincinnati.

EXPLANATION OF PLATE 5

FIGURE — PAGE

1—*Cusacrinus nodobrachiatus* (WACHSMUTH & SPRINGER), S1,192, hypotype, Springer collection, Hampton formation, Le Grand, Iowa. Illustrated as typical of the species; a gerontic specimen. This specimen shows the infolded arms of this species. × 1 14

2—*Cusacrinus nodobrachiatus* (WACHSMUTH & SPRINGER), same specimen as in Figure 1. Enlarged photographs show the incurling arms of this species. *2a*, view of the tegmen, infolded arms, pinnular hooks and nodes on the brachials. *2b*, view of the outer extensions of the arms and distal pinnules. All figures × 3 14

3—*Cusacrinus viaticus* (WHITE), 8525, holotype, U. S. National Museum, Lower Carboniferous, Mountain Spring, Old Mormon Road, Nevada. × 3 17

4—*Cusacrinus viaticus* (WHITE), same specimen as in figure 3, retouched and with sutures drawn onto the photograph. × 1 17

1a

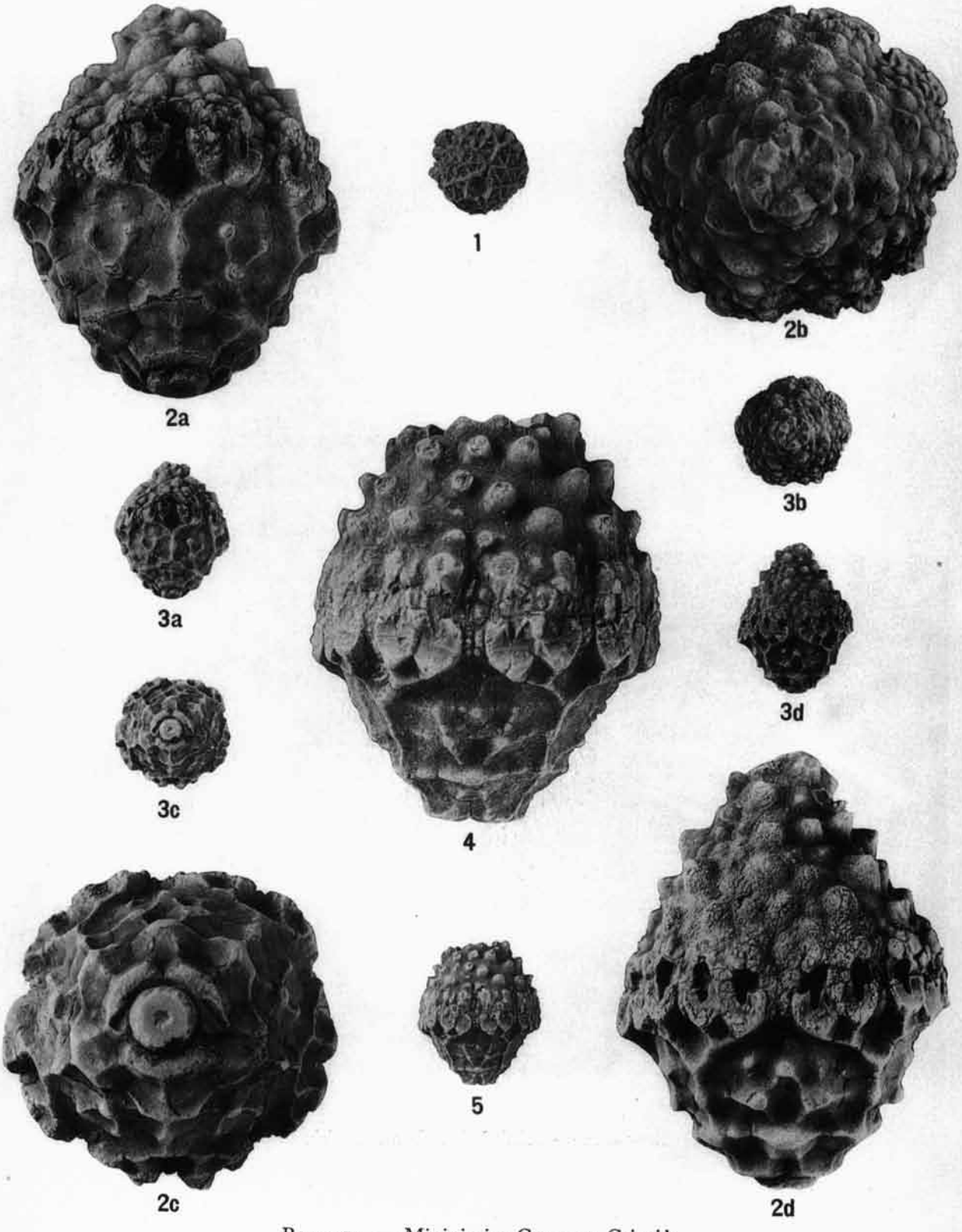
4

3

2a

2b

BOWSHER — Mississippian Camerate Crinoids



BOWSHER — Mississippian Camerate Crinoids

Nunnacrinus jessieae (MILLER & GURLEY) BOWSHER n. comb.

Actinocrinus jessieae MILLER & GURLEY, 1896b, p. 32, pl. 2, fig. 15, 16. ——— MILLER, 1897, p. 731.
Actinocrinites jessieae (MILLER & GURLEY) BASSLER & MOODEY, 1943, p. 298.

Occurrence.—Burlington limestone, Sedalia, Mo.

Holotype.—2229, Miller collection, University of Cincinnati; 3 paratypes, 2229a, Miller collection, University of Cincinnati.

Nunnacrinus locellus (HALL) BOWSHER, n. comb.

Plate 3, figures 4a-d

Actinocrinus locellus HALL, 1861b, p. 15. ——— MILLER, 1889, p. 218.
Cactocrinus reticulatus (HALL) WACHSMUTH & SPRINGER, 1897, p. 605. ——— WELLER, 1898, p. 156. ——— BASSLER & MOODEY, 1943, p. 344.

Hall's original description is as follows:

"ACTINOCRINUS LOCELLUS (n.s.). Body somewhat broadly turbinate below the arms. Basal plates short, spreading in a tripartite rim over the summit of the column. Radials hexagonal; the third supporting on the upper sloping faces large supraradials, which support what appear to be brachial plates, except on the anal division of the postero-lateral rays, where second supraradials rest on one side and brachials on the other, giving five arms to each ray; making the arm-formula $\frac{\frac{4}{4}\quad 4}{5\quad 5} = 22$.

"Interrarial plates six or seven in each series. Anal plates 10 to 13, in series of one, two, four, four, etc. Surface of plates marked by strong angular ridges toward the margins, terminating in a central rounded or somewhat transverse node.

"This species resembles in form the *A. fosteri* of McCHESNEY; but differs in having a less expanded cup, and also in the arm-formula. Burlington limestone."

Although this species has been considered by most workers to be conspecific with *Actinocrinus reticulatus* HALL (Pl. 4, fig. *1a-c*) it differs from *A. reticulatus* in having a more steeply conical cup, more delicate ornamentation, different posterior rays, and in having the rays separated at the base of the arms.

Occurrence.—Lower Burlington limestone, Burlington, Iowa.

Types.—Lectotype, S1,222, C. A. White Collection, Springer Collection, U. S. National Museum, Washington, D. C.; paratype, S4,629, same collection.

Nunnacrinus mammillatus BOWSHER, n. sp.

Plate 3, figures *6a,b* and *7a,b*, Plate 6, figures *2a-e*, *3a-d*, and text figs. 3*A-D*

Actinocrinus proboscidialis HALL (*partim*) SPRINGER, 1884, p. 101.
Cactocrinus proboscidialis (HALL) (*partim*). WACHSMUTH & SPRINGER, 1897, p. 601-602.
Cactocrinus multibrachiatus (HALL) (*partim*). LAUDON & BOWSHER, 1941, pp. 2156-2157.
Cactocrinus(?) cf. *C. multibrachiatus* (HALL) (*partim*). LAUDON & BOWSHER, 1949, pp. 61, 64, 65, 67, 70.

Diagnosis.—A small nunnacrinid with conical tegmen, conical to slightly bowl-shaped dorsal cup, strong anal tube with nodose plates, strong bosses on plates of the dorsal cup, strong median ray ridge, radiating ridges strong on most plates of the cup, rays separated laterally by two elongate interradial plates and each ray with a small *iIIIBr*.

Description.—The plates of the rays are ornamented by strong median ray ridges which extend from the *BB* to the base of each arm. The median ray ridge is developed into a boss in the center of the $IBrr_1$ and on some specimens similar bosses are developed on the $IBrr_2$ and *IIBrr*. The shape of the *B* cone is variable. In all specimens the lower half of the dorsal surfaces of the *BB* lie in a plane; the circatrix of the column also lies in this plane, but the cone formed by the upper half of the dorsal surfaces of the *BB* varies in shape from low to steeply conical. Each *R* is marked by a strong transverse ridge which extends to adjacent *RR*. The center of each interradial plate has a prominent boss from which weak to moderately strong ridges extend to adjacent plates. The strength of these radial ridges seems quite variable. Each ray is separated from adjacent rays by two narrow, elongate interradial plates; interradial area contiguous with tegmen. Each ray is separated into two halves by a single, slightly elongate *iIIIBr*. Although the arms of each ray are grouped and the

---

EXPLANATION OF PLATE 6

IIIBrr expand slightly beyond the general contour of the dorsal cup, the upper parts of the rays are not protuberant.

The plates in the interradial areas are 1 + 2 + 2 + 2 and in the posterior interradius X + 2 + 3 + 2 + 2.

The distal surface of each $IIIBrr_1$ bears a set of muscle and ligament fossae and a fulcral ridge (Pl. 6, fig. 2*d*, 3*a*) marking these surfaces as representing the top of the dorsal cup and the base of the arms of the crinoid. The fulcral ridges and fossae are prominent in this species.

The conical tegmen is composed of numerous regularly polygonal plates and merges into the stout anal tube. Each plate of the tegmen and anal tube is produced into mammillary nodes. The plates of the tegmen vary considerably in size and consequently the nodes on the tegmen are of various sizes. The so-called "radial dome" plates are not recognizable. The position of the subtegminal ambulacra is shown by the shape of the lower margin of the tegmen and by the concentration of numerous small plates in the tegmen just above each *Amb* opening.

The anal tube is not preserved on any of the specimens but is inferred to be quite stout and nodose because of the characters of the plates forming the base of the anal tube.

One or possibly two columnals are distinguished on the holotype but are so poorly preserved that they tell nothing of the characters of the column.

Remarks.—The strong degree of variation in the surface sculpture of this species, coupled with the fact that we still do not know how much variation to consider as infraspecific in such a group of fossils as these make it very difficult, if not impossible at this time, to delimit precisely the range of variation for the species. Although all specimens of *Nunnacrinus mammillatus* are from the lower part of the Nunn member of the Lake Valley formation (LAUDON & BOWSHER, 1949, p. 13) there remains a problem of chronological relations of individual specimens referred to the species, because the specimens from the Nunn member most commonly are obtained only after they are freed from the matrix by natural weathering and are found lying loose on hillsides. However, most specimens referred to the species have come from the lower 30 to 60 feet of the Nunn member and are fairly distinctive.

N. mammillatus is separable readily from all other described species of *Nunnacrinus*. It differs from *Nunnacrinus dalyanus* (MILLER), also from the Nunn member of the Lake Valley formation, in having the rays separated from one another by two interradial plates rather than one, by its smaller size, less conical cup, weaker plate sculpture, less conical tegmen, and greater irregularity of size of tegmen plates.

N. mammillatus differs from *N. rubra* WELLER in having a more steeply conical cup and tegmen, stronger ornamentation, more nodose tegmen, and rays more closely spaced.

SPRINGER (1884, p. 101) reported *Actinocrinus proboscidialis* HALL from limestones at Lake Valley, New Mexico, which he called lower Burlington limestone. Several lots of crinoids in the Springer collection from Lake Valley, identified by SPRINGER as *Cactocrinus proboscidialis* (HALL) include examples of *N. mammillatus*, but no specimens in these lots are properly identified as *C. proboscidialis*. Specimens of *N. mammillatus* in these lots are segregated; Springer collection S1,218 and S4,620. The reported occurrence of *Cactocrinus proboscidialis* in the Lake Valley formation, Lake Valley, New Mexico (SPRINGER, 1884, p. 101; WACHSMUTH & SPRINGER, 1897, p. 602) is erroneous, being based on misidentified specimens. This reported occurrence is in part based on the species *N. mammillatus* and other undescribed species of *Nunnacrinus*. *C. proboscidialis* is very distinct from *N. mammillatus* in having quadrangular, rather than hexagonal $IBrr_1$, rays in contact all around at arm level, a distinctly different type of surface sculpture, domed tegmen rather than a conical one, and a less nodose tegmen composed of fewer plates. All species of *Cactocrinus* can be distinguished readily from this species of *Nunnacrinus* by the structure of the interradial areas at arm level.

Occurrence.—Lower part of the Nunn member, Lake Valley formation, Mimbres Mountains, New Mexico.

Types.—Holotype (114,695) and 15 paratypes (S1,218, S4,620, 118,026, 118,027 and 118,028) from USNM loc. 3,027, slopes and scarps on Apache Hill, one mile north of Lake Valley, approx. SE NW sec. 21, T. 18 S., R. 7 W., Sierra County, New Mexico; one paratype (118,029) from USNM loc. 3,027B, scarp south of Apache Hill just northeast of Lake Valley, approx. SW sec. 21, T. 18 S., R. 7 W., Sierra Co., New Mexico; two paratypes (118,030) from USNM loc. 3,028, hillside slope (southwest side) of scarp approx. 0.7 miles northwest of J. P. Nunn Ranch on Tierra Blanca Creek, approx. SE NW sec. 10, T. 17 S., R. 8 W., Sierra Co., New Mexico; one paratype (118,031) from USNM loc. 3,030, exposures to north of Trujillo Creek on west-facing scarp along canyon running north from Trujillo Creek, approx. 3.3 miles S. 50° E. of Hillsboro, approx. cen. north line sec. 26, T. 16 S., R. 7 W., Sierra Co., New Mexico; and one paratype (118,032) from USNM loc. 3,032, exposures 200 yards due north of house on North Percha Creek at the junction of North Percha Creek trail and ranger trail, approx. SW sec. 24, T. 16 S., R. 9 W., Sierra Co., New Mexico.

Nunnacrinus pallubrum (MILLER & GURLEY) BOWSHER, n. comb.

Actinocrinus pallubrum MILLER & GURLEY, 1896b, p. 26, pl. 1, fig. 25-27. ——— WELLER, 1898, p. 61.
Actinocrinus pollubrum (misspelling) MILLER & GURLEY, MILLER, 1897, p. 731.
Actinocrinites pallubrum (MILLER & GURLEY) BASSLER & MOODEY, 1943, p. 272.

Occurrence.—Burlington limestone, Sedalia, Mo.

Types.—Whereabouts not known.

Nunnacrinus pettisensis (MILLER & GURLEY) BOWSHER, n. comb.

Actinocrinus pettisensis MILLER & GURLEY, 1896b, p. 6, pl. 1, fig. 304. ——— MILLER, 1897, p. 731, fig. 1279. ——— WELLER, 1898, p. 62.
Actinocrinites pettisensis (MILLER & GURLEY) BASSLER & MOODEY, 1943, p. 273.

Occurrence.—Burlington limestone, Sedalia, Mo.

Holotype.—2,226, Miller collection, University of Cincinnati; 2,226a, 67 paratypes, Miller collection, University of Cincinnati.

Nunnacrinus rubra (WELLER) BOWSHER, n. comb.

Actinocrinus rubra WELLER, 1909, p. 285, pl. 11, fig. 4,5.
Actinocrinites rubra (WELLER) BASSLER & MOODEY, 1943, p. 273.
Actinocrinites ruber (misspelling) (WELLER) MOORE & LAUDON, 1944, p. 193, pl. 76, fig. 2.

Occurrence.—Fern Glen limestone.

Type.—Whereabouts of the type or types not known.

Nunnacrinus sampsoni (MILLER & GURLEY) BOWSHER, n. comb.

Actinocrinus sampsoni MILLER & GURLEY, 1896b, p. 5, pl. 1, fig. 1,2. ——— MILLER, 1897, p. 731. ——— WELLER, 1898, p. 62.
Actinocrinites sampsoni (MILLER & GURLEY) BASSLER & MOODEY, 1943, p. 273.

At present there exists no homonymy concerning the specific names used in combinations *Aacocrinus sampsoni* (MILLER & GURLEY) (1895) and *Nunnacrinus sampsoni* (MILLER & GURLEY) (1896); therefore, both names are considered available (HEMMING, 1950, p. 105) although PECK & KEYTE (1938, p. 83) incorrectly published a new name *Actinocrinus milleri* to replace *Actinocrinus sampsoni* (MILLER & GURLEY) 1895, which is the earlier of the pair of names.

Occurrence.—Burlington limestone, Sedalia, Mo.

Type.—Whereabouts of the type or types not known to the writer.

Nunnacrinus, sp. A

Plate 3, figures *5a-c*

Actinocrinus reticulatus HALL, 1861, p. 2.

The type lot of *Actinocrinus reticulatus* HALL, C. A. White collection, contained three specimens of actinocrinitids which are referred herein to different species. HALL's original description (1861a, p. 2) seems to have been based on one of these specimens; whereas, his subsequent description (1861c, p. 269) seems to be based on other specimens. The specimen best fitting the original description (HALL, 1861, p. 2) is retained as S1,223 and herein designated as lectotype of *Actinocrinus reticulatus* HALL, which is referred to the genus *Cactocrinus* and not discussed (Pl. 4, fig. *1*). The specimen best fitting HALL's subsequent description (1861c, p. 269) is an undescribed species of *Nunnacrinus* (Pl. 3, fig. *5a-c*) but is not named in this paper because of undetermined synonomy concerning this and several related species. The specimen (Pl. 3, fig. *5a-c*) is recatalogued as *Nunnacrinus* sp. A, S4,628, C. A. White collection. A third specimen (Pl. 6, fig. 1) in the type lot (S4,627) appears to be a new species of *Cactocrinus* but is not named because of problems of synonomy.

Occurrence.—Burlington limestone, Burlington, Iowa.

Specimen.—S4,628 (out of S1,223), C. A. White collection, Springer collection, U. S. National Museum, Washington, D. C.

Species doubtfully referred to Nunnacrinus.—A number of species of actinocrinitids described by DE KONINCK & LE HON (1854) from the Tournaisian of Belgium are referred to this genus, although it is possible that a new genus should be proposed to include these species. Also doubtfully assigned to *Nunnacrinus* is the crinoid described by ROWLEY & HARE as *Actinocrinus puteatus.*

Nunnacrinus armatus (DE KONINCK & LE HON) BOWSHER, n. comb.

Actinocrinus armatus DE KONINCK AND LE HON, 1854, p. 138, pl. 4, fig. *4a-c.*
Actinocrinites armatus (DE KONINCK AND LE HON) BASSLER & MOODEY, 1943, p. 267.

Occurrence.—Échantillon de l'argile, Carbonifère de Tournay.

Types.—Believed to be in the DE KONINCK collection of the École des Mines, Paris, or the DE KONINCK collection of the Musée Royale d'Histoire Naturelle, Brussels.

Nunnacrinus deornatus (DE KONINCK & LE HON) BOWSHER, n. comb.

Actinocrinus deornatus DE KONINCK AND LE HON, 1854, p. 142, pl. 3, fig. 5a,b.
Actinocrinites deornatus (DE KONINCK & LE HON) BASSLER & MOODEY, 1943, p. 269.

Occurrence.—Échantillon de l'argile carbonifère de Tournay.

Types.—Believed to be in the DE KONINCK collection of the École des Mines, Paris, or the DE KONINCK collection of the Muséum Royale d'Histoire Naturelle, Brussels.

Nunnacrinus dorsatus (DE KONINCK & LE HON) BOWSHER, n. comb.

Actinocrinus dorsatus DE KONINCK AND LE HON, 1854, p. 139, pl. 4, fig. 5a,b.
Actinocrinites dorsatus (DE KONINCK AND LE HON) BASSLER & MOODEY, 1943, p. 269.

Occurrence.—Échantillon de l'argile carbonifère de Tournai.

Types.—Believed to be in the DE KONINCK collection of the *École des Mines,* Paris, or the DE KONINCK collection of the Musée Royale d'Histoire Naturelle, Brussels.

Nunnacrinus puteatus (ROWLEY & HARE) BOWSHER, n. comb.

Actinocrinus puteatus ROWLEY & HARE, 1891, p. 101, pl. 2, fig. 16.

Cactocrinus lucina (HALL) WACHSMUTH & SPRINGER, 1897, p. 603. ——— WELLER, 1898, p. 155. ——— BASSLER & MOODEY, 1943, p. 342.

Occurrence.—Base of the lower Burlington limestone at Louisiana, Mo.

Types.—Probably Rowley collection, University of Illinois, Urbana, Ill.

Nunnacrinus stellaris (DE KONINCK & LE HON) BOWSHER, n. comb.

Actinocrinus stellaris DE KONINCK AND LE HON, 1854, p. 136, pl. 3, fig. 3a-b, 4a-g, and pl. 4, fig. 3.

Actinocrinites stellaris (DE KONINCK AND LE HON) BASSLER & MOODEY, 1943, p. 274.

Occurrence.—Échantillon de l'argile carbonifère de Tournai.

Types.—Believed to be in the DE KONINCK collection of the École des Mines, Paris, or the DE KONINCK collection of the Muséum Royale d'Histoire Naturelle, Brussels.

ACKNOWLEDGMENTS

I wish to express thanks to W. T. ALLEN, U. S. National Museum, for help on some of the photography, and to my colleagues, Drs. J. B. KNIGHT, E. KIRK, A. H. CLARK, and G. A. COOPER for numerous discussions concerning technical aspects of problems encountered in the study.

REFERENCES

AUSTIN, T. & AUSTIN, T. JR. (1842) *Proposed arrangement of the Echinodermata, particularly as regards the Crinoidea and a subdivision of the Class Adelostella (Echinidae):* Ann. and Mag. Nat. Hist., ser. 1, vol. 10, p. 106-113 (no plates or figures).

——— (1843) *Descriptions of several new genera and species of Crinoidea:* same, vol. 11, p. 195-207 (no plates or figures).

BASSLER, R. S. (1938) *Pelmatozoa Palaeozoica (generum et genotyporum index et bibliographia):* Fossilium Catalogus, I, Animalia, para. 83, p. 1-149, W. Junk, 's-Gravenhage.

——— & MOODEY, M. W. (1943) *Bibliographic and faunal index of Paleozoic pelmatozoan echinoderms:* Geol. Soc. America, Spec. Paper, no. 45, p. 1-733.

BEVERIDGE, T. R. (1951) *The geology of the Weaubleau Creek area, Missouri:* Missouri Geol. Survey and Water Resources, 2nd ser., vol. 32, p. 1-111, pl. 1-12, fig. 1-5.

BRANSON, E. B., *et al.* (1938) *Stratigraphy and paleontology of the Lower Mississippian of Missouri:* Univ. Missouri Studies, vol. 13, no. 3, p. 1-180, pl. 1-20, fig. 1-9; no. 4, p. 1-234, pl. 21-48, fig. 10-18.

CLARK, A. H. (1915) *A monograph of the existing crinoids, The Comatulids:* U. S. Nat. Mus., Bull. 82, vol. 1, pt. 1, p. 1-406, pl. 1-17, 602 figs.

HALL, JAMES (1859) *Contributions to the palaeontology of Iowa:* Geol. Rept. Iowa, vol. 1, pt. 2, p. 473-724, pl. 1-29.

——— (1860) *Contributions to the palaeontology of Iowa; being descriptions of new species of Crinoidea and other fossils:* Suppl. to vol. 1, pt. 2, Geol. Rept. Iowa, p. 1-94, pl. 1-3.

——— (1861a) *Descriptions of new species of Crinoidea and other fossils, from the Carboniferous rocks of the Mississippi Valley:* Albany, N. Y., p. 1-12. ("Read before Boston Society of Natural History, Dec. 19, 1860. Abstract from the full descriptions now in press, with additional species.") (25 or so copies prepared and distributed on Feb. 14, 1861 by HALL.)

——— (1861b) *Descriptions of new species of Crinoidea; from the investigations of the Iowa Geological Survey, Preliminary Notice:* Albany, N. Y., p. 1-18. (This paper consists of the same 12 pages as published at Albany, on Feb. 14, 1861, plus 6 pages, a cover and an illustration of *Trematocrinus typus* on the back of the cover. HALL (inside of front cover) states that, "The first twelve pages of this paper were published and distributed on the fourteenth day of February, 1861, and the entire paper, in its present form, is published according to the date of the imprint on the title page (February 26, 1861)." Records published in the Trans. St. Louis Acad. Sci. (1861, vol. II, p. 151) support Hall's claim for the date of this paper.

——— (1861c) *Descriptions of new species of Crinoidea from the Carboniferous rocks of the Mississippi Valley:* Boston Soc. Nat. Hist., Jour., vol. 7, pt. 2, art. 4, p. 261-328. (Although Springer, 1928, accepted the signature date of January, 1861, for this paper, no valid reason is seen for recognizing it. I have not been able to determine the exact date of publication of the paper, however. HALL (1861a, 1861b) cites the Albany papers as abstracts of the full descriptions then in press. Hence I believe that the paper in the Jour. Boston Soc. Nat. Hist. must have appeared later than Feb. 25, 1861. HALL would have had no reason to publish the abstracts, if this were not the case.)

——— (1863) *Preliminary notice of some species of Crinoidea from the Waverly sandstone of Summit County, Ohio, supposed to be of the age of the Chemung group of New York:* Printed in advance from 17th Rept. on New York State Cabinet Nat. Hist., Albany, N. Y., p. 1-11 (Nov. 11, 1863).

——— (1864) *Preliminary notice of some species of Crinoidea from the Waverly sandstone of Summit County, Ohio, supposed to be of the age of the Chemung Group of New York:* 17th Rept. on condition of New York State Cabinet Nat. Hist., Appendix H, p. 50-60.

——— (1872) *Photographic plates and explanations of plates:* State Mus. Nat. Hist. [New York], Bull. 1, pl. 1-7. (Specimens illustrated are described in 15th Rept. New York State Cabinet Nat. Hist.; 24th Rept. New York State Mus.; Boston Jour. Nat. Hist., vol. 7; Geol. Rept. Iowa, vol. 1, pt. 2, and Iowa Suppl. to vol. 1, pt. 2).

——— & WHITFIELD, R. P. (1875) *Description of Crinoidea from the Waverly group, Paleontology, part 2:* Rept. Geol. Survey Ohio, vol. 2, p. 162-179, pl. 11, 12.

HEMMING, FRANCIS (1950) *The official record of proceedings of the International Commission on Zoological Nomenclature at its session held in Paris in July 1948:* Bull. Zool. Nomencl., vol. 4, pts. 4-6, p. 63-158 (May 25, 1950).

KAISER, PHILLIP (1950) *Stratigraphy of Lower Mississippian rocks in southwestern Missouri:* Am. Assoc. Petroleum Geologists Bull., vol. 34, no. 11, pp. 2133-2175, fig. 1-8.

KEYES, C. R. (1894) *Paleontology of Missouri:* Missouri Geol. Survey, vol. 4, pt. 1, p. 1-271, pl. 1-32.

KIRK, EDWIN (1943) *Identification of Actinocrinus chloris Hall:* Washington Acad. Sci., Jour., vol. 33, no. 11, p. 346-347.

——— (1946) *Stiptocrinus, a new camerate crinoid genus from the Silurian:* Washington Acad. Sci., Jour., vol. 36, no. 2, p. 33-36.

KONINCK, L. G. DE, & LE HON, H. (1853) *Recherches sur les crinoïdes du terraine carbonifère de la Belgique:* Extrait du Recueil des Mémoires, Acad. Roy. Belgique, vol. 28, mém. 3, p. 1-208, pl. 1-7.

LAUDON, L. R. (1931) *The stratigraphy of the Kinderhook series of Iowa:* Iowa Geol. Survey, vol. 35, p. 333-451, fig. 1-24.

——— (1933) *The stratigraphy and paleontology of the Gilmore City formation of Iowa:* Iowa Univ. Studies, Studies Nat. Hist., n. ser., no. 256, p. 1-72, pl. 1-19, fig. 1-7.

——— & BEANE, B. H. (1937) *The crinoid fauna of the Hampton formation at LeGrand, Iowa:* Same, no. 345, p. 227-273, pl. 1-19, fig. 1-7.

——— & BOWSHER, A. L. (1941) *Mississippian formations of Sacramento Mountains, New Mexico:* Am. Assoc. Petroleum Geologists, Bull., vol. 25, p. 2107-2160, figs. 1-31.

——— (1949) *Mississippian formations of southwestern New Mexico:* Geol. Soc. America, Bull., vol. 60, p. 1-88, fig. 1-44.

MCCHESNEY, J. H. (1860) *Descriptions of new species of fossils from the Palaeozoic rocks of the western states:* private publ., Albany, N. Y., p. 1-76.

——— (1865) *Plates illustrating in part the new species of fossils from the Palaeozoic rocks of the western states, and two new species noticed March, 1860:* private publ., Albany, N. Y., title page and pl. 1-11, with explanations (pub. April, 1865).

——— (1868) *Descriptions of fossils from the Palaeozoic rocks of the western states, with illustrations:* Chicago Acad. Sci., Trans., vol. 1, p. 1-57, pl. 1-9.

MEEK, F. B., & WORTHEN, A. H. (1869) *Descriptions of new Carboniferous fossils from the western states:* Acad. Nat. Sci. Philadelphia, Proc., p. 137-172.

——— (1873) *Descriptions of invertebrates from the Carboniferous system:* Illinois Geol. Survey, vol. 5, p. 323-619, pl. 1-32.

MILLER, S. A. (1881) *Subcarboniferous fossils from the Lake Valley mining district of New Mexico, with descriptions of new species:* Cincinnati Soc. Nat. Hist., Jour., vol. 4, p. 306-315, pl. 7.

——— (1889) *North American geology and palaeontology:* Cincinnati, Ohio, p. 1-664.

——— (1891) *Palaeontology:* Adv. Sheets, 17th Rept. Geol. Survey Indiana, p. 1-103, pl. 1-20.

——— (1892a) *Palaeontology:* 17th Rept. Geol. Survey Indiana, p. 611-705, pl. 1-20.

——— (1892b) *Palaeontology:* Adv. Sheets, 18th Rept. Geol. Survey Indiana, p. 1-79, pl. 1-12.

——— (1892c) *First appendix to North American geology and palaeontology:* Cincinnati, Ohio, p. 665-718.

——— (1894) *Palaeontology:* 18th Rept. Geol. Survey Indiana, p. 257-333, pl. 1-12.

——— (1897) *2nd appendix to North American geology and palaeontology:* Cincinnati, Ohio, p. 719-793.

——— & GURLEY, W. F. E. (1893) *Description of some new species of invertebrates from the Palaeozoic rocks of Illinois and adjacent states:* Illinois State Mus. Nat. Hist., Bull. 3, p. 1-81, pl. 1-8.

——— (1894) *New genera and species of Echinodermata:* Same, Bull. 5, p. 1-53, pl. 1-5.

——— (1895a) *Description of new species of Palaeozoic Echinodermata:* Same, Bull. 6, p. 1-62, pl. 1-5.

——— (1895b) *New and interesting species of Palaeozoic fossils:* Same, Bull. 7, p. 1-89, pl. 1-5.

——— (1896a) *Description of new and remarkable fossils from the Palaeozoic rocks of the Mississippi Valley:* Same, Bull. 8, p. 1-65, pl. 1-5.

——— (1896b) *New species of crinoids from Illinois and other states:* Same, Bull. 9, p. 1-66, pl. 1-5.

——— (1896c) *New species of Echinodermata and a new crustacean from the Palaeozoic rocks:* Same, Bull. 10, p. 1-91, pl. 1-5.

——— (1897) *New species of crinoids, cephalopods, and other Palaeozoic fossils:* Same, Bull. 12, p. 1-70, pl. 1-5 (with index to Bull. 3-12).

MOORE, R. C. (1928) *Early Mississippian formations in Missouri:* Missouri Bur. Geology and Mines, ser. 2, vol. 21, p. 1-283, pl. 1-13, fig. 1, 2.

——— & LAUDON, L. R. (1943) *Evolution and classification of Paleozoic crinoids:* Geol. Soc. America, Spec. Paper, no. 46, p. 1-167, pl. 1-14, fig. 1-18.

——— (1944) *Class Crinoidea: in* SHIMER, H. W. & SHROCK, R. R., Index fossils of North America, Wiley & Sons, New York, p. 137-205, pl. 52-79.

PECK, R. E., & KEYTE, I. A. (1938) *Crinoidea of the Chouteau limestone:* Univ. Missouri Studies, vol. 13, no. 4, p. 70-108, pl. 27-31.

ROWLEY, R. R. (1906) *Descriptions of fossils: in* GREENE, Contr. to Indiana Paleontology, New Albany, Ind., vol. 2, pt. 2, p. 31, pl. 6.

——— & HARE, S. J. (1891) *Some new species of Echinodermata:* Kansas City Sci., vol. 5, no. 7, p. 97-103, pl. 2.

SPRINGER, FRANK (1884) *On the occurrence of the lower Burlington limestone in New Mexico:* Am. Jour. Sci., ser. 3, vol. 27, p. 97-103.

WACHSMUTH, C. W., & SPRINGER, F. (1881) *Revision of the Palaeocrinoidea, pt. 2:* Philadelphia Acad. Nat. Sci., Proc. 1881, p. 177-414, pl. 17-19 (Separates repaged, p. 1-238, pl. 17-19).

——— (1890) *New species of crinoids and blastoids from the Kinderhook group of the Lower Carboniferous rocks at Le Grand, Iowa, and a new genus from the Niagara group of western Tennessee:* Illinois Geol. Survey, vol. 8, p. 155-208, pl. 15-17.

——— (1897) *North American Crinoidea Camerata:* Harvard College Mem. Mus. Comp. Zool., vol. 21, 22, p. 1-897, pl. 1-83, fig. 1-21.

WELLER, STUART (1898) *A bibliographic index of North American Carboniferous invertebrates:* U. S. Geol. Sur., Bull. 153, p. 1-653.

——— (1909) *Kinderhook faunal studies—V, Fauna of the Fern Glen:* Geol. Soc. America, Bull., vol. 20, p. 265-332, pl. 10-15.

WHITE, C. A. (1874) *Preliminary report upon invertebrate fossils collected by expeditions of 1871, 1872, and 1873, with descriptions of new species:* U. S. Geol. Survey West of 100th Merid. (Wheeler) p. 1-27.

——— (1877) *Report upon the invertebrate fossils collected in portions of Nevada, Utah, Colorado, New Mexico and Arizona by parties of the expeditions of 1871, 1872, 1873, and 1874:* U. S. Geol. Survey West of 100th Merid., vol. 4, pt. 1, p. 1-219, pl. 1-21.

WHITFIELD, R. P. (1893) *Republication of descriptions of Lower Carboniferous Crinoidea from the Hall collection now in the American Museum of Natural History, with illustrations of the types not heretofore figured:* Am. Mus. Nat. Hist., Mem., vol. 1, pt. 1, p. 1-37, pl. 1-3.

WILSON, H. E. (1916) *Evolution of the basal plates in monocyclic Crinoidea Camerata:* Jour. Geol., vol. 24, no. 5, p. 488-508; no. 6, p. 533-553; no. 7, p. 665-684.

WOOD, ELVIRA (1914) *The use of crinoid arms in studies of phylogeny:* New York Acad. Sci., Ann., vol. 24, p. 1-17.

WRIGHT, JAMES (1943) *Notes on Actinocrinites elephantinus Austin and Amphoracrinus brevicalix Rofe:* Geol. Mag., vol. 80, p. 231-236, pl. 8.