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FOSSIL CRINOID STUDIES

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CONTENTS

PART 1

NEW LECANOCRINID FROM PENNSYLVANIAN OF OKLAHOMA

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ABSTRACT

A new lecanocrinid from Oklahoma of early Missourian (Late Pennsylvanian) age is referred to the genus *Cibolocrinus* WELLER. It is one of the largest lecanocrinids known and represents a divergent group in which the dorsal cup has a basal concavity.

Discussion of *Tribrachiocrinus* M'COY and possible affinities is given, leading to the conclusion that this genus belongs to the Inadunata rather than the Flexibilia.

INTRODUCTION

Specimens of a large *Cibolocrinus* from the Seminole Formation, lower Missourian, south of Glenpool, Oklahoma, have been known to me for several years. They occurred in a soft clay-shale and most were found as a clump of disarticulated pieces which had to be carefully gathered and glued together. Each plate is slightly different from other plates so that a complete reconstruction of a cup, using plates from different individuals, is virtually impossible. The large broad cup of *C. seminolensis* STRIMPLE,

new species, is distinctive but generally agrees with the cups of *C. detrusus* STRIMPLE (1951b) from the Oologah Formation (Desmoinesian) and *C. abyssus* STRIMPLE (1951b) from the Wann Formation (Missourian). All species have a broad basal invagination as well as wide cups, which characters separate them from other known species of *Cibolocrinus*. Apparently a distinct lineage is represented within the genus, but separation is not proposed at this time.

MORPHOLOGICAL FEATURES OF CIBOLOCRINUS

The narrow articular facets of the radials of *Cibolocrinus* serve to distinguish the dorsal cups from associated inadunates. The tripartite nature of the infrabasal circlet in these inadunatelike forms is also found in many Late Paleozoic inadunates but without duplication of the articulating processes of *Cibolocrinus,* which are as follows:

1. The sides of the radials are thickened inwardly to produce a short shelf for reception of primibrachs.
2. A well-defined outer ligament pit is formed which terminates on each side considerably short of the sutures.
3. The area behind the outer ligament pit is not so pronounced a ridge as the transverse ridge of inadunates, but is a raised area which in many specimens is marked by irregular denticulation.
4. Shallow, confluent troughlike depressions are present on each side of the interradial sutures and taper into long grooves which pass behind the transverse ridge. These are probably muscle scars.
5. The center of the articulating facet is narrower than the sides but there is no pronounced notch.

Among known inadunates a group under the Ampelocrinidae have narrow articulating facets which, however, lack the troughlike depressions which cross the interradial sutures (see 4 above). WANNER (1930, pl. 1, fig. 4) has given an enlarged photograph of the latter type of articulating facet for the Permian lecanocrinid *Petrocrinus beyrichi* WANNER (1930). Summit views of the dorsal cups of *Cibolocrinus conicus* STRIMPLE (1951b, pl. 2, fig. 3) or *C. detrusus* STRIMPLE (1951b, pl. 1, fig. 4) demonstrate similar articulating structures. MOORE (1939, text-fig. 3c) illustrated the distal articulating facet of the radial of *C. banioni* MOORE (1939).

AFFINITIES OF TRIBRACHIOCRINUS

The genus *Tribrachiocrinus* M'COY (1847) has as its type species *T. clarkei* M'COY (1847). Whatever affinities are found for *T. clarkei* will therefore determine the placement of the genus. PHILIP (1964) redescribed and figured the holotype of this species and concluded that it is a dicyclic inadunate crinoid, an interpretation with which most authorities agree. Of greater importance, he clarified the morphology of the species.

PHILIP (1964, p. 199) took issue with a statement by STRIMPLE (1951b, p. 201) as follows: "In a study of an entirely different problem, Dr. R. C. MOORE and the author concluded that *Tribrachiocrinus* probably belongs to the Flexibilia rather than the Inadunata." Several other comments were made by STRIMPLE in this discussion. For example, concerning WRIGHT's species *T. caledonicus* he said "It is certain that his species is a highly specialized inadunate and probably it should be referred to a new genus." It may be noted that WRIGHT (1952) followed this suggestion and referred it to a new genus *Hosiecrinus*. The discussion by STRIMPLE (1951a, p. 200-201) was centered on a specimen of *Delocrinus* sp. in which the ability to support an arm had been lost by the right anterior (*B*) radial. This is the only recorded instance of such a condition among erisocrinids of Pennsylvanian age.

It appears that PHILIP was unaware of the study by STRIMPLE (1951b, pl. 2, fig. 4-5) in which a specimen of *Cibolocrinus* sp. was figured showing suppression of arms in both the right anterior (*B*) and left anterior (*E*) rays, exactly as in *Tribrachiocrinus clarkei*. The radial facets of *Cibolocrinus* are like those of *T. clarkei* contrary to statement by PHILIP (1964, p. 201) that "the deep transverse ligament pit is suggestive of inadunate rather than flexible crinoid affinities." Unless the family Lecanocrinidae should be transferred to the Inadunata, the deep outer ligament pit is also found in the Flexibilia. It should be noted that YAKOVLEV (1934, p. 277, 278) has indeed ascribed *Cibolocrinus* to the sub-

family Graphiocrininae BATHER of the Fistulata (Inadunata) but this assignment has not been accepted by others.

Concerning the infrabasal circlet PHILIP (1964, p. 201) stated, "Moreover, in the Upper Palaeozoic Flexibilia the infrabasal circlet is greatly diminished in size, so that it is often concealed entirely by the stem." The infrabasal circlet of *Cibolocrinus* (*e.g., C. seminolensis*) is not so broad as in *Tribrachiocrinus clarkei* but is quite normal for any upper Paleozoic crinoid. Placement of the smaller infrabasal in the anterior (*A*) radius of *T. clarkei* is not conclusive but is indicative of a difference. The small infrabasal is typically in the right posterior (*C*) radius among the lecanocrinids.

Another major feature discussed by PHILIP (1964, p. 201) concerned the large anal plates, of which three occur within the dorsal cup of *Tribrachiocrinus clarkei*. This is the most conclusive evidence for considering the genus to be an inadunate and was the reason STRIMPLE (1951a, p. 201) used the word "probably" in suggesting that *Tribrachiocrinus* might be a flexible. It must be remembered, however, that many lecanocrinids have two anal plates and in rare specimens three anal plates (the two upper plates in series). It would be no great change for a right tube plate to fall into place within the cup under certain conditions, just as happens in many inadunates.

I am inclined to agree with PHILIP in placing *Tribrachiocrinus clarkei* in the Inadunata upon the basis of presently known evidence but this crinoid does not seem to be closely related to *Sundacrinus* WANNER (1916). The latter genus has five infrabasals, typically has one anal plate but may have two, and the distal articulating facets are much broader than found in *T. clarkei*. PHILIP intimated relationship of *Tribrachiocrinus* with the family Sundacrinidae. He wrote of several genera "These forms may be conveniently placed together in the family Sundacrinidae MOORE & LAUDON, which is therefore confined to the Permian of Australia, Timor and Russia." He included *Tetrabrachiocrinus* YAKOVLEV (1934), which is from the Permian of Sicily. This form has a large stem which completely covers the infrabasals and most of the surface of the basals, a shallow cone-shaped cup, and a wide posterior interradius composed of three large anal plates. The nonarm-bearing radial plates retain a normal width. PHILIP included *Indocrinus* WANNER (1916), which genus has pore slits at the angles of the plates. *Indocrinus* has been assigned to the Indocrinidae STRIMPLE (1966), together with *Proindocrinus* YAKOVLEV (1939) and *Metaindocrinus* STRIMPLE (1966), all of which have a peculiar shape much like a Japanese lantern, and have one anal followed above by two smaller anal plates which may or may not be within the dorsal cup. Other possibly related genera mentioned by PHILIP are *Parindocrinus* WANNER (1937) (which is probably related to the Indocrinidae) and *Hemiindocrinus* YAKOVLEV (1926). It has been propounded by YAKOVLEV (1949, p. 897-900) that *Ulocrinus globulus* (currently assigned to the genus *Ureocrinus* WRIGHT & STRIMPLE, 1945) is the progenitor of *Indocrinus,* with *Hemiindocrinus* and *Proindocrinus* in the lineage.

Further study of these unusual forms is needed before clearly defined affinities are established.

SYSTEMATIC PALEONTOLOGY

Order SAGENOCRINOIDEA Springer, 1913

Family LECANOCRINIDAE Springer, 1913

Genus CIBOLOCRINUS Weller, 1909

CIBOLOCRINUS SEMINOLENSIS Strimple, new species
Figure 1,*1-12*

DESCRIPTION.—Dorsal cup low, wide, truncate, bowl-shaped, with pronounced broad basal concavity. Three infrabasals form subhorizontal disc at bottom of basal concavity, smallest infrabasal in right posterior (*C*) ray. Proximal portions of five large basals form sides of basal concavity and curve upward to form part of sides of cup. Large oblique facet developed for contact with each infrabasal and well-defined depressions indicate existence of ligamental tissue between plates. Basals quite thin but widen slightly between each apex, with groovelike depressions marking suture faces; thin margins of sutures bear fine denticles.

Radials pentagonal, twice as wide as long, their transverse profile gently curved in midsection and nearly straight at each side, which gives cup, when viewed from above, appearance of having ten sides. Straight transverse ridge

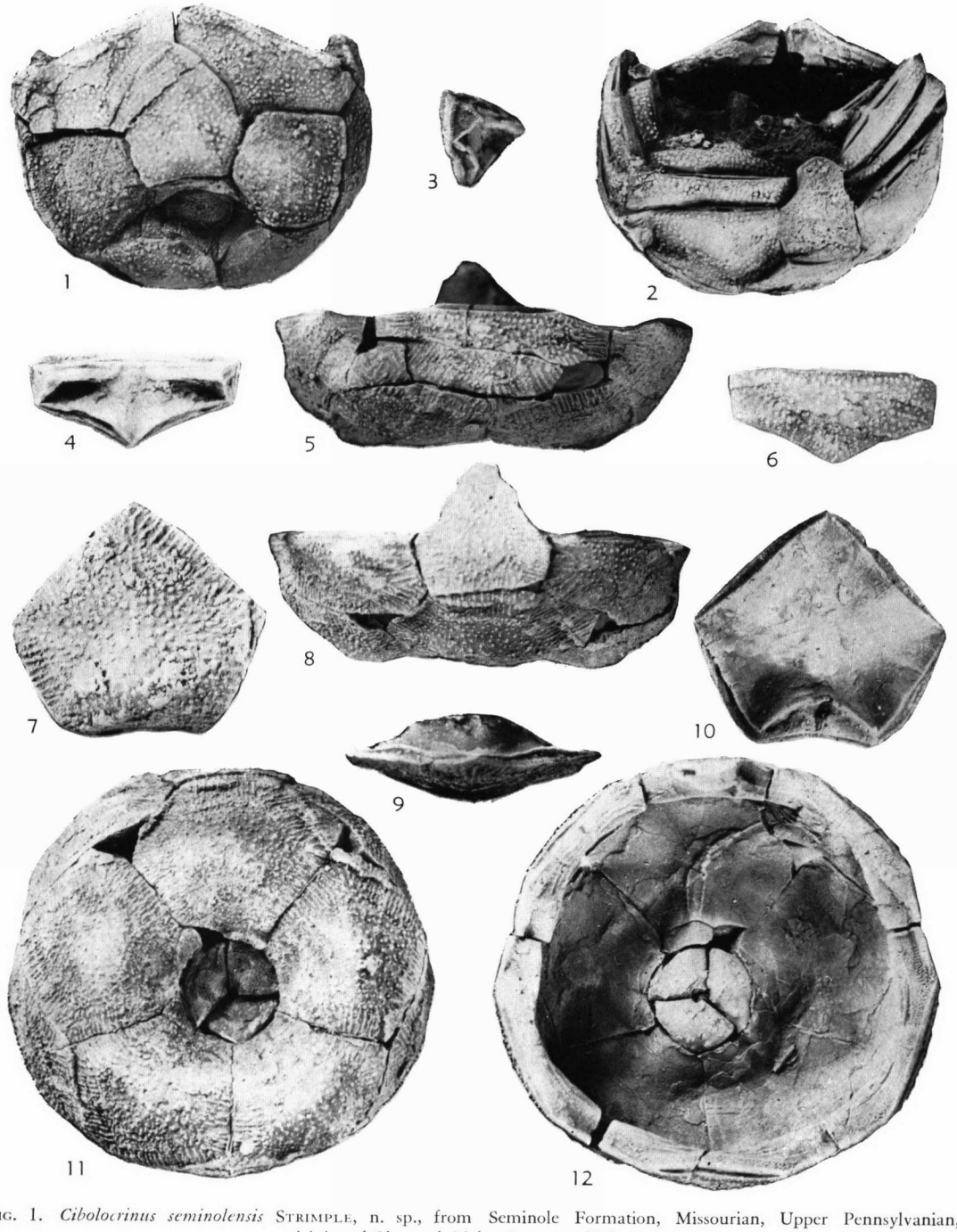

FIG. 1. *Cibolocrinus seminolensis* STRIMPLE, n. sp., from Seminole Formation, Missourian, Upper Pennsylvanian, vicinity of Glenpool, Tulsa County, Oklahoma.

1-2. Oblique side and oblique summit views of partial crown, paratype (SUI 31802).

3-4,6. Side, interior, and exterior views of radial plate, paratype (SUI 31804).

5,8,11-12. Anterior, posterior, base and summit views of dorsal cup, holotype (SUI 31801).

7,9-10. Exterior, interior, and summit views of basal plate, paratype (SUI 31803).

marked by denticles intersects margin of upper articulating facet several millimeters from summit of interradial sutures, and deeply excavated outer ligament area somewhat shorter than ridge. Facet is short in mid-section where no shelf is developed but widens slightly on each side where short shelves are developed which are confluent with those of adjoining plates and apparently supported muscles, because first brachials extend over entire surface and have matching depressions.

Single anal plate large, resting evenly upon the posterior basal and extending well above summit of cup. Adjoining arms are attached to the anal plate where depressions for attachment of muscles are also found.

Proximal portions of arms attached to figured paratype are wide, short elements, branching on second primibrach. Secundibrachs are also short, wide elements.

Columnar scar is wide, sharply impressed, circular in outline and pierced by small star-shaped lumen. Attachment area covers most of infrabasal circlet, but appreciable portions of infrabasals are exposed. Random denticles mark cicatrix but no regular pattern has been observed.

Surface of plates covered by small, sharp nodes and long, thin ridges, latter crossing from basal to basal, from basal to radial (or to anal plate) and from radial to radial (or to anal plate). Central area of each basal and upper mid-portion of each radial are mildly tumid and appear to be focal points of ridge pattern.

Measurements (in millimeters) of Holotype of Cibolocrinus seminolensis.

[* Measurements taken along surface curvature. **Measurements taken along surface curvature to transverse ridge.]

Width of cup, maximum	44.0
Width of cup, minimum (anteroposterior)	42.7
Height of cup	13.2
Diameter of infrabasal circlet	12.2
Height of basal concavity	6.8
Length of (*BC*) basal plate (right posterior)	21.5*
Width of (*BC*) basal plate (right posterior)	22.6*
Length of (*E*) radial plate (left anterior)	13.0**
Width of (*E*) radial plate (left anterior)	26.5*
Length of anal X	14.6
Width of anal X	13.0

REMARKS.—*Cibolocrinus seminolensis* STRIMPLE, n. sp., is the largest described species of the genus and has a structure comparable to that of *C. abyssus* STRIMPLE (1951b) and *C. detrusus* STRIMPLE (1951b). The latter is the ancestor and the former a descendant of *C. seminolensis.* Ornamentation of *C. detrusus* is different in that sporadic pimple-like nodes on the surface of the plates are formed rather than the well-developed thin ridges of *C. seminolensis. C. abyssus* has a mildly granular surface and longer distal articulating facets of the radials, and the sides of the cup are more erect than found in *C. seminolensis.* These are the only species of *Cibolocrinus* having a well-defined basal concavity.

OCCURRENCE.—Seminole Formation, Skiatook Group, Missourian, Pennsylvanian; roadcut on east side of combined U.S. Highways U.S. 169 and 75, about 0.75 mile south of Glenpool, NW¼, NW¼ sec. 23, T. 17 N., R. 12 E., Tulsa County, Oklahoma.

TYPES.—Holotype SUI 31801 (State University of Iowa); paratype (partial crown) SUI 31802, paratype (figured basal plate) SUI 31803, paratype (figured radial plate) SUI 31804, paratypes (partial cup and disarticulated plates) SUI 31805, paratype (partial dorsal cup) OU 5599 (University of Oklahoma).

ILLUSTRATIONS.—Figure 1,*1-12.*——*1-2.* Oblique side and oblique summit views of partial crown, paratype (SUI 31802).——*3-4,6.* Side, interior and exterior views of radial plate, paratype (SUI 31804).——*5,8,11-12.* Anterior, posterior, base, and summit views of dorsal cup, holotype (SUI 31801).——*7,9-10.* Exterior, interior, and summit views of basal plate, paratype (SUI 31803). All figures approximately ×1.4.

REFERENCES

(See consolidated list following Part 6.)

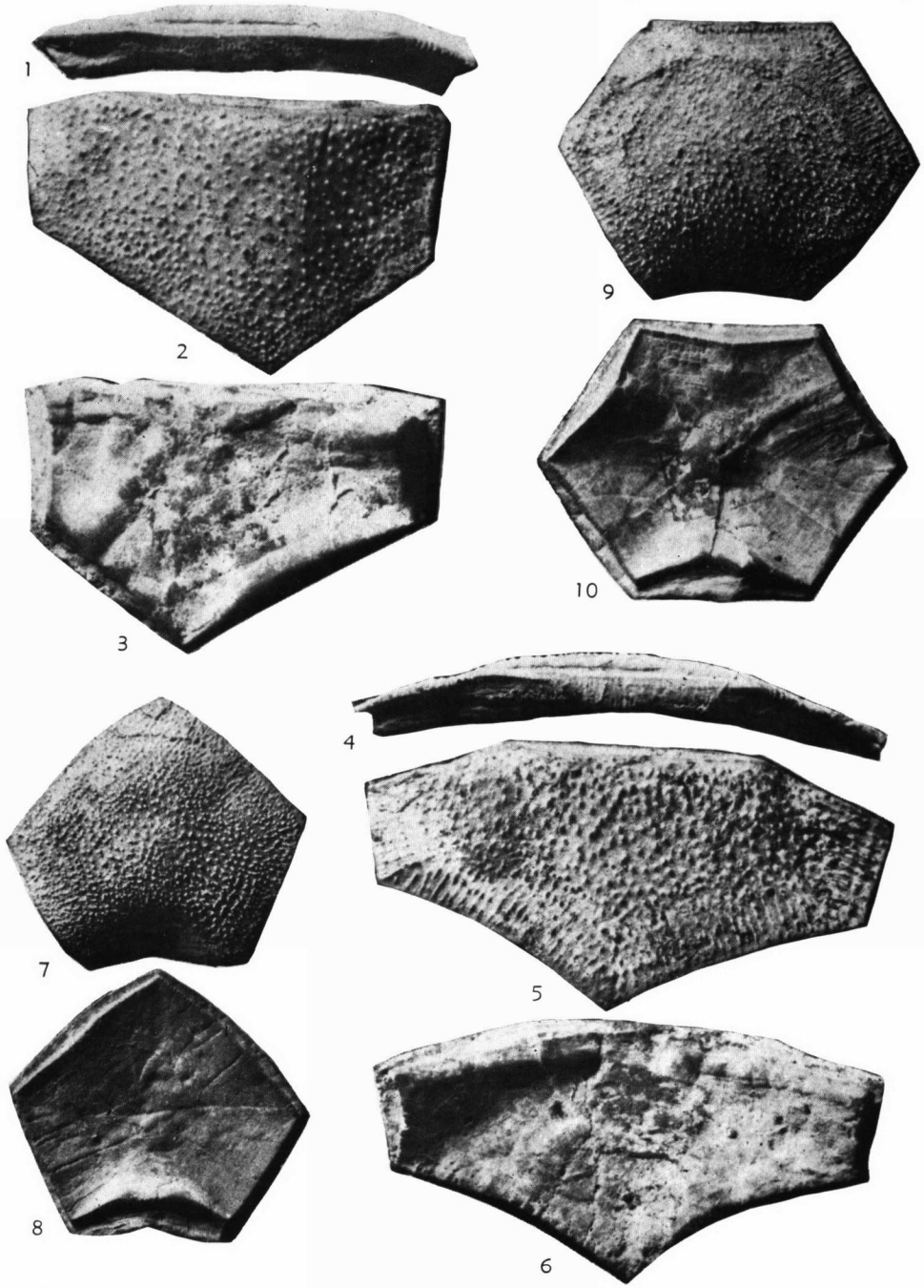

FIG. 2. *Cibolocrinus seminolensis* STRIMPLE, n. sp., Coffeyville Formation, Missourian, Upper Pennsylvanian, Kansas.

1-3. Facetal, exterior, and interior views of *D* radial, type specimen (UKPI Pef5a), identified as to placement in dorsal cup by truncated right edge *(2)*, which adjoined quadrangular anal X plate (not found), ×3.

4-6. Facetal, exterior, and interior views of another radial (UKPI Pef 5b), which originally belong to *A, B,* or *E* rays, as shown by its bilateral symmetry, ×3.

7-8. Exterior and interior views of basal plate (UKPI Pef04a) belonging to interray other than *CD,* as indicated by its pointed distal (upper) extremity, ×3.

9-10. Exterior and interior views of large hexagonal basal plate (UKPI Pef4b) belonging to CD (posterior) interray, its wide distal margin indicating unusual width of anal X, which originally articulated with this edge, ×3.

ADDENDUM—OCCURRENCE OF CIBOLOCRINUS SEMINOLENSIS STRIMPLE, N. SP., IN SOUTHERN KANSAS

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An interesting consequent of the preparation of the foregoing paper by STRIMPLE and its submittal to me as editor of *The University of Kansas Paleontological Contributions* for proposed publication in this series was my immediate recognition that the new species named *Cibolocrinus seminolensis* is easily and positively identifiable as equivalent to an already published, differently named species described by MOORE and R. M. JEFFORDS in a relatively comprehensive report, issued in March, 1967 by the Esso Production Research Company, Houston, Texas. Because the report is "for Company use only," it does not qualify as a scientific work in which new genera, species, and suprageneric taxa can be accepted under provisions of the international zoological *Code* (1961). Names for them given in this report lack standing in application of the Law of Priority.

The study by MOORE & JEFFORDS was directed to demonstrating the usefulness of disarticulated and dissociated skeletal remains of fossil crinoids, and the new species of *Cibolocrinus* described by them was based on an assemblage of discrete thecal plates (basals, radials) and one infrabasal circlet attached to a basal. No anal *X* plate was seen but the exceptionally wide distal sutural face of a posterior basal (differentiated from other basals by its hexagonal outline and greater width) showed that the missing anal *X* must be an unusually large plate, presumably with form and projection above the rim of the radial circlet typical of the genus. The shapes and dimensions of the various thecal plates studied by MOORE & JEFFORDS correspond closely to those figured by STRIMPLE, but most significantly they display identical ornament of the exterior surfaces consisting of minute, sharp-pointed, closely-spaced tubercles which become aligned to form knife-edged ridges running perpendicularly to the interradial and radial-basal sutures (Fig. 2). The distinctiveness of this ornament is sufficient by itself for determination of *C. seminolensis*.

The fossils reported by STRIMPLE come from the Seminole Formation in southern Tulsa County, Oklahoma, whereas those of MOORE & JEFFORDS from lower Coffeyville beds at Coffeyville, Montgomery County, southern Kansas. Both occurrences are very little above the base of Missourian strata which form the bottom part of deposits classed as Upper Pennsylvanian. They are identical or near-identical in age and thus support the contention that crinoids are excellent fossils for precise stratigraphic correlations and age determinations. If disarticulated and dissociated crinoid remains can be employed for these purposes, as demonstrated by the example of *Cibolocrinus seminolensis,* researches on fragmentary crinoid fossils should be enhanced in value for such materials outnumber articulated specimens in the ratio of many millions to one. Geographically, the Oklahoma and Kansas discoveries of *C. seminolensis* are only 52 miles apart in airline distance, whereas very similar occurrences of other crinoid species are separated by hundreds and even thousands of miles. A paper by MOORE & JEFFORDS (1968) records near-identical species of crinoids recognized by distinctive features of stem parts and other skeletal remains found in deposits of closely similar age in such widely separated areas as central United States of America, northwestern and central Europe, southwestern, central, and northeastern Asia, Australia, and the East Indies.

Acknowledgment and appreciation are expressed to the Esso Production Research Company for permission to publish this note.

PART 2

UPPER PENNSYLVANIAN ANOBASICRINID FROM NEW MEXICO

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ABSTRACT

A crinoid crown from Upper Pennsylvanian deposits in New Mexico is identified by coglike contacts of radials and infrabasals of its dorsal cup as belonging to the genus *Schistocrinus* and is similar enough to the type species to be designated as *S.* sp. aff. *S. torquatus*. Relationships of this crinoid to *Anobasicrinus* and *Synyphocrinus* are considered.

INTRODUCTION

A crown of the genus *Schistocrinus* in relatively good preservation was discovered by me a few years ago in the Stainbrook Collection, reposited at The University of Iowa, with label indicating that it came from "Jemez Springs, New Mexico." In response to an inquiry, F. H. HARLOW of Los Alamos, New Mexico, was able to establish the horizon as an exposure of the Jemez Springs Shale Member, Madera Formation, Virgilian, in Church Canyon at the north edge of the village of Jemez Springs. The locality is reported by SUTHERLAND & HARLOW (1967, p. 1066). DENNIS BURDICK, a graduate student at The University of Iowa, checked the exposure in the fall of 1967 in my behalf. The specimen is closely related to the form described as *Synyphocrinus permicus* LANE & WEBSTER (1966), as modified by WEBSTER & LANE (1967), but has the coglike infrabasal circlet (in broad contact with radials) of *Schistocrinus torquatus* MOORE & PLUMMER and therefore here is referred to as *S.* sp. aff. *S. torquatus*.

SYSTEMATIC PALEONTOLOGY

ANOBASICRINIDAE Strimple, 1961

GENERA.—*Anobasicrinus* STRIMPLE, 1961; *Synyphocrinus* TRAUTSCHOLD, 1881; *Schistocrinus* MOORE & PLUMMER, 1940.

DISCUSSION.—With the discovery of new Permian crinoids in southern Nevada by WEBSTER & LANE (1967, p. 15) it appears that *Synyphocrinus permicus* LANE & WEBSTER (1966) is a representative of the genus *Anobasicrinus* STRIMPLE (1961). It also appears that the Moscovian (Atokan[1]) species of *Synyphocrinus cornutus* TRAUTSCHOLD (1881) and *S. magnus* YAKOVLEV & IVANOV (1956) belong to the family, although they are more primitive in structure than *Anobasicrinus,* since *Synyphocrinus* has a high cup and evolutionary change normally is from a high cone-shaped cup with erect infrabasals to a low cone-shaped cup with moderately upflared or subhorizontal infrabasals. Hyperpinnulation is difficult to distinguish unless specimens are in ideal preservation. One brachial of an undescribed species of *Anobasicrinus* from the LaSalle Formation of Illinois has two pinnular attachment facets on one side which demonstrates hyperpinnulation, and the existence of four pinnules to a brachial may be inferred. *A. praecursor* (MOORE & PLUMMER, 1940) was reported to have four pinnules on some brachials but some have only two pinnules. *A. permicus* (Lane & Webster), STRIMPLE, new combination, is reported to be hyperpinnular. *Schistocrinus torquatus,* as represented by the present specimen, has occasional hyperpinnulation.

Morrowan species of *Anobasicrinus* (e.g., *A. obscurus* STRIMPLE, 1961) have a flattened base, which indicates that evolution of *Anobasicrinus* from the high cone-shaped cup took place in Mississippian time. The arms of *Synyphocrinus cornutus* appear to be 12 to a ray, which would produce 60 arms, the same number as found in *A. bulbosus. Plummericrinus* MOORE & LAUDON (1943) and *Glaukosocrinus* STRIMPLE (1951) are no longer considered to be anobasicrinids.

OCCURRENCE.—Pennsylvanian and Lower Permian; Russia and North America.

[1] Or lower Desmoinesian.

Genus SCHISTOCRINUS Moore & Plummer

TYPE SPECIES.—*Schistocrinus torquatus* MOORE & PLUMMER, 1940.

DIAGNOSIS.—Dorsal cup low, truncate bowl-shaped, base nearly flat except for sharply depressed, vertically walled, round stem impres-

FIG. 3. *Schistocrinus* sp. aff. *S. torquatus* MOORE & PLUMMER *(1-2); Quantoxocrinus goldringae* (BELANSKI) *(3,4); Belanskicrinus westoni* (BELANSKI) *(5).*

1-2. Schistocrinus sp. aff. *S. torquatus* MOORE & PLUMMER; hypotype (SUI 32474) from *AB* interray and *DE* interray, Jemez Springs Shale, Madera Formation, Virgilian, Upper Pennsylvanian, Church Canyon, Jemez Springs, New Mexico, approximately ×1.6.

3,4. Quantoxocrinus goldringae (BELANSKI); *3,* holotype (CHB 1981) viewed from *AB* interray; *4,* paratype (CHB 1983) (left specimen) viewed from *AB* interray, approximately ×2.

5. Belanskicrinus westoni (BELANSKI), paratype (CHB 1675) (right specimen) with infrabasals and basals missing, viewed from *B* ray, approximately ×2.

sion; sides of cup gently and rather evenly flaring; surface smooth; sutures distinct but not impressed. Five infrabasals not visible from side, except distal extremity of right posterior (*C*) infrabasal in posterior view, each infrabasal truncated distally for contact with radials, infrabasal circlet resembling a cog-wheel. Five basals small, subquadrangular, and shaped like arrowheads, not laterally in contact. Five radials large, hexagonal, slightly wider than long, proximally in contact with infrabasals, their outward sloping articular facets slightly narrower than maximum width of plates. Three anal plates in dorsal cup, radianal resting on right posterior (*C*) infrabasal and supporting large principal anal (*X*) and right tube plate (*RX*), which are mostly above summit line of radials; large tube plate rests on upper margins of *X* and *RX*.

Remarks.—The above description is essentially that originally given except that reference to the arm structure and anal pyramid is deleted because it has been demonstrated by Strimple (1961) that species purported to show those structures belong to another genus. These are *confertus* and *parvus* which were ascribed to *Sciadiocrinus*. The species *Malaiocrinus azygous* was transferred by Strimple (1961, p. 93) to *Schistocrinus,* for it was demonstrated (ibid., pl. 9, fig. 1-2) to have a bulbous anal sac and lower arms, resembling those of texacrinids. The arms were not well enough preserved to be certain of close affinities. On the basis of the presently considered specimen *Schistocrinus* is transferred to the family Anobasicrinidae. The arms are almost identical with those of *Anobasicrinus,* even to occasional hyperpinnulation.

Occurrence.—Desmoinesian-Virgilian, Pennsylvanian: Oklahoma, Kansas, New Mexico.

SCHISTOCRINUS sp. aff. S. TORQUATUS Moore & Plummer, 1940

Figure 3,*1-2*

Description.—A full and comprehensive description of the dorsal cup of the species is given in the generic diagnosis. The dorsal cup of the present specimen is slightly twisted but all essential features are preserved. The broadly truncated distal ends of the infrabasals were found in all rays by careful preparation of the specimen. The vertically walled, large, round stem impression is distinctive. One well-preserved basal plate discloses the shape termed "arrowhead" by Moore & Plummer (1940). The arms of the holotype of *Schistocrinus torquatus* are not known and the anal plates of the present specimen are missing so that a positive conspecific identification is not warranted. The arms all branch on a broad, low primibrach 1. Another isotomous bifurcation takes place, usually on secundibrach 3 or 4. Thereafter, one endotomous branching usually occurs. The brachials have well-rounded exteriors, are of medium length, have even sutures, and may be hyperpinnulated. Pinnules are moderately long and slender. The overall length of the crown, as preserved, is 58 mm., of which 50 mm. consist of arms. The cup is about 25.5 mm. wide.

Remarks.—Comparison of *Schistocrinus torquatus* with the older *S. azygous* (Strimple, 1949) shows the former to have a somewhat shallower, more flared dorsal cup with more pronounced union between radials and infrabasals.

Hypotype.—SUI 32474, deposited in the Department of Geology, The University of Iowa, Iowa City.

Occurrence.—Jemez Springs Shale Member, Madera Formation, Upper Pennsylvanian (Virgilian), at Jemez Springs, New Mexico.

Illustrations.—Figure 3,*1-2*.——*1*. Hypotype (SUI 32474) from *AB* interray.——*2*. Hypotype from *DE* interray. Figures approximately ×1.6.

REFERENCES

(See consolidated list following Part 6.)

PART 3

PENNSYLVANIAN CRINOIDS FROM OHIO AND OKLAHOMA

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ABSTRACT

A resurvey of crinoids from Carbon Hill in Hocking County, Ohio, was made resulting in the discovery of a new species of *Graffhamicrinus* in addition to the formerly known species, *G. somersi,* and *Plaxocrinus mooresi.* The crinoids are reported to occur probably in the McArthur Member of the Pottsville Formation and appear to be of early Desmoinesian or late Atokan age. *P. mooresi* is rather closely related to *P. dornickensis.* A unique morphologic feature is bulged shape of the first primibrachs in such manner as to provide a stop against the outer surface of the adjoining radial plates when the arms were extended. Spinose axillaries of the arms, together with the spinose terminating plates at summit of the anal sac, produced a formidable array of spines when the arms were closed.

Formational rank of the Pumpkin Creek Limestone of southern Oklahoma is recommended.

INTRODUCTION

The occurrence of Pennsylvanian crinoids at Carbon Hill, in Hocking County, Ohio has been documented for many years. WHITFIELD (1882) described two species as *Zeacrinus mooresi* and *Cyathocrinus* [*Cyathocrinites*] *somersi.* MORNINGSTAR (1922) illustrated some additional specimens from the same locality. Through the kindness of J. H. PECK Jr., University of California, Berkeley, the original type specimens were loaned. The specimens studied by MORNINGSTAR, as well as some additional material, was loaned through courtesy of THOMAS J. M. SCHOPF and WALTER C. SWEET, The Ohio State University, Columbus, Ohio, where the material is deposited in the Orton Museum. New illustrations of the original types specimens and some additional materials have been prepared and *Graffhamicrinus conspicuus* STRIMPLE, n. sp., is proposed for a new form.

STRATIGRAPHIC NOTES

MORNINGSTAR (1922) did not seem to know whether the crinoids described by her were obtained from the upper Pottsville Formation or the lower Allegheny Formation, but thought they were from the McArthur Member, which in that area is reported to be about 23 feet above the upper Mercer Limestone. The distinctive spinose primibrachs of *Plaxocrinus mooresi* (WHITFIELD, 1882) are very common and are almost identical with primibrachs found in a shale below the massive limestones of the Pumpkin Creek Limestone, in Love County, Oklahoma. The Love County specimens were thought to be conspecific until an almost complete dorsal cup was found in October 1966, showing a more pronounced basal concavity than is found in *P. mooresi.* It is thought to be closer to *P. dornickensis* STRIMPLE, although the primibrachs are usually more swollen than those found associated with *P. dornickensis,* which species is typically from higher in the formation.

Graffhamicrinus is represented in the McArthur Limestone by *G. somersi* (WHITFIELD) and *G. conspicuus,* STRIMPLE, n. sp. The species *Delocrinus aristatus* STRIMPLE has been reported from the Pumpkin Creek Limestone and was assigned to *Graffhamicrinus* by STRIMPLE (1961) but it has a broader, lower cup and is probably a derivative of *Diphuicrinus* MOORE & PLUMMER (1937).

The type locality of the Pumpkin Creek Limestone is grown over with brush and grass so that a paucity of fossils, or of exposed rock for that matter, exists. However, in October 1966 I made

a diligent search and found a substantial limestone ledge and some fossils just across the section line in sec. 30, T. 6 S., R. 2 E., Love County, Oklahoma, as well as some fossils on the east side of Pumpkin Creek. TOMLINSON reported the Pumpkin Creek Limestone to be 70 feet thick, with 20 feet of shale and the remainder limestone. The beds are well exposed in the abandoned quarry near Tucker Tower Museum (NE¼ sec. 15, T. 6 S., R. 2 E., Love County) and are fossiliferous.

The Pumpkin Creek Limestone has been considered to be Desmoinesian in age for many years. It was originally proposed as a member of the Dornick Hills Formation which subsequently has been designated as a group. It is a well known unit of many years standing and it is here proposed to give it formational status as Pumpkin Creek Limestone Formation. The unit underlying it is called the Frensley Limestone but the name is probably not valid. The next unit below is the Lester Limestone, which was considered to be Atokan in age for many years but recently has been classified as Desmoinesian by CRONOBLE & WADDELL (1966) based on the presence of *Fusulina insolita* THOMPSON and other primitive species of *Fusulina*. The species *F. insolita* occurs typically in rocks of Atokan (Derryan) age so the situation requires some clarification.

MORNINGSTAR (1922) reported the species *Zeacrinus* [=*Plaxocrinus*] *mooresi* from the Boggs Limestone and from the lower and upper Mercer limestones, based on disarticulated plates. One would expect some closely related forms of *Plaxocrinus* in the lower horizons. *Fusulinella iowensis* THOMPSON has been reported by THOMPSON (1936) from the lower and upper Mercer limestones, and the absence of *Fusulina s.s.* is also noted so that an Atokan age for these rocks may be inferred. Correlations have been attempted with selective brachiopods, especially *Kozlowskia haydenensis* and *Mesolobus striatus,* but these forms have a long range, having been reported from upper beds as well (e.g., Putnam Hill Formation and Vanport Formation of Ohio). The two brachiopod species have been found by me in association with *Fusulina* sp. cf. *F. pumila* in the Frensley Limestone in Johnston County, Oklahoma.

In conclusion, the crinoids of the McArthur Limestone suggest correlation with the lower part of the Pumpkin Creek Limestone or the upper part of the Frensley? Limestone or early Desmoinesian age.

SYSTEMATIC PALEONTOLOGY

Order INADUNATA Wachsmuth & Springer

Suborder DENDROCRINOIDEA Bather

Family PIRASOCRINIDAE Moore & Plummer

Genus PLAXOCRINUS Moore & Plummer

TYPE SPECIES.—*Hydreionocrinus crassidiscus* MILLER & GURLEY.

DISCUSSION.—The genus *Plaxocrinus* was redefined by STRIMPLE (1961) to include species with elongated spines on the first primibrach of all arms but with no spines on other axillaries. The imperfectly preserved arms of *P. mooresi* show that upper axillaries are projected as slender spines. The dorsal cup of the type species has an almost imperceptible basal concavity and the basal plates extend upward into the lateral walls of the cup so as to be readily visible in side view of the cup, whereas in *P. mooresi* there is a decided basal concavity and only the outermost tips of the basal plates are visible in side view of the cup. *P. dornickensis* is also atypical in having a pronounced basal concavity but the two species are not removed from the genus at this time. *L.Penn.-M.Penn.*

PLAXOCRINUS MOORESI (Whitfield), 1882

Figure 4,*3-7,11-15;* Figure 5,*1-3,7*

DESCRIPTION.—Dorsal cup low, truncate bowl-shaped with greatest width from right to left at summit plane; wide depressed posterior interradius and shallow basal concavity present. Infrabasals normally 5 (*A* and *B* infrabasals fused in holotype) forming broad subhorizontal disc at bottom of basal concavity; internally, infrabasals form low dome. Five mildly tumid, large basal plates form sides of basal concavity, flexing sharply to provide broad basal plane and curved upward at their summit; only tips of basals visible in side view of cup. Five large, wide radials provided bulk of lateral walls of cup, their surfaces sloping gently upward and outward until they approach articulating shelves where they flex upward sharply; broad, shallow notches present between articulating radial facets at sum-

mit of cup and outer surfaces extending in between upper facets, which slope gently outward and show pronounced muscular fossae. Three anal plates in normal (primitive) arrangement are relatively wide elements. Arms branch on first primibrachs which are broad, bulged and extended as long spines, bulges so developed and placed as to provide stop against outer surface of

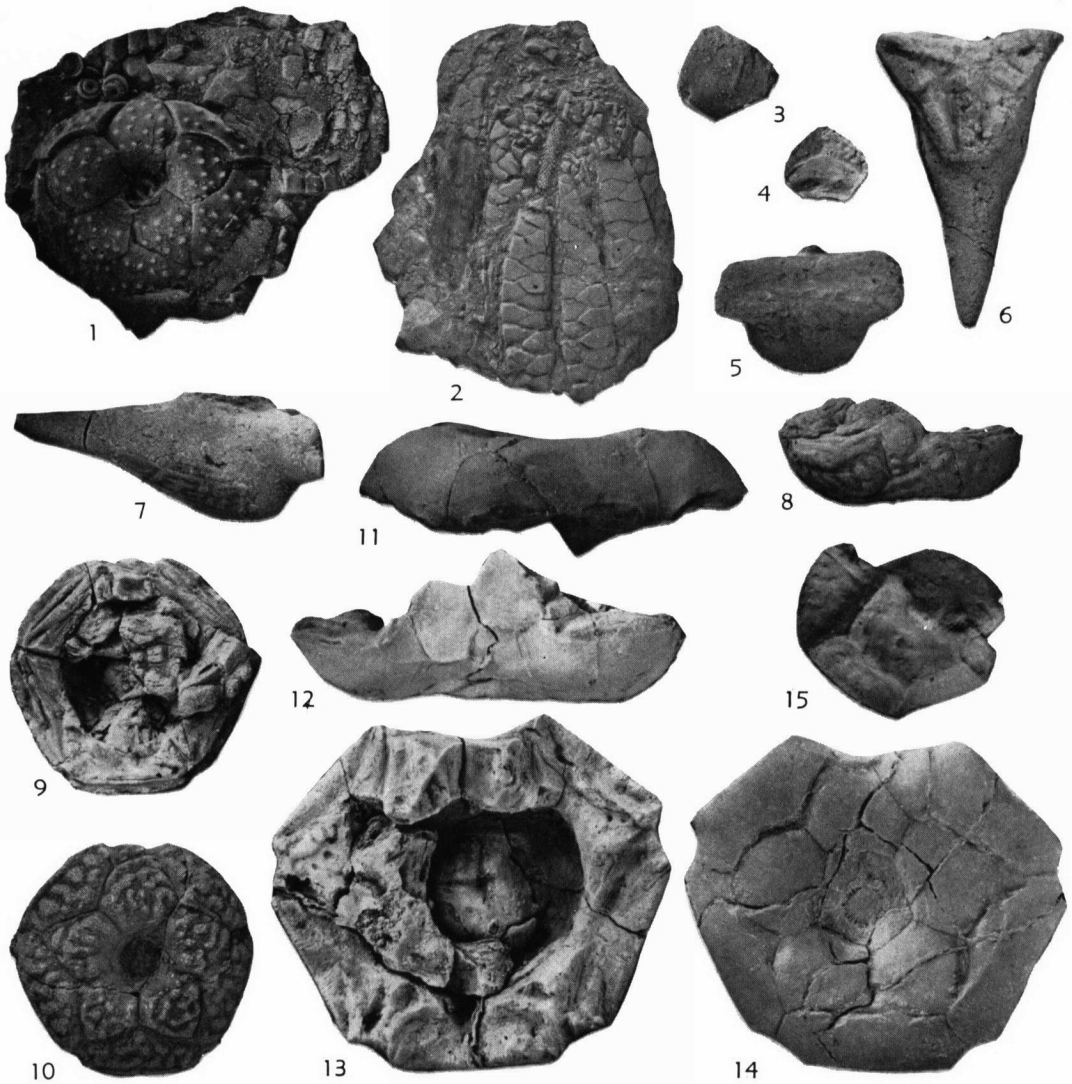

FIG. 4. *Graffhamicrinus conspicuus* STRIMPLE, n. sp. *(1-2); G. somersi* (WHITFIELD) *(8-10); Plaxocrinus mooresi* (WHITFIELD) *(3-7,11-15).*

1-2. Graffhamicrinus conspicuus STRIMPLE, n. sp.; holotype (OM 15781) viewed from below and side view of upper arms.

3-7,11-15. Plaxocrinus mooresi (WHITFIELD); *3,4,* hypotype (OM 24528) basal plate from exterior and oblique view from distal end showing irregular topography of suture faces, ×3; *5-7,* lectoparatype U.Cal. 34231), spinose first primibrach viewed from side, above, and end; *11-14,* lectoholotype (UC 34232) dorsal cup viewed from anterior (summit down) and posterior sides, summit, and base; *15,* radial plate, hypotype (OM 24528) oblique view showing irregular topography of suture faces.

8-10. Graffhamicrinus somersi (WHITFIELD), lectotype (U.Cal. 1349/34227) view from *CD* interray, summit view and basal view. All specimens except *3* and *4* approximately ×1.8, from McArthur Limestone?, early Desmoinesian, Lower Pennsylvanian, Carbon Hill, Hocking County, Ohio.

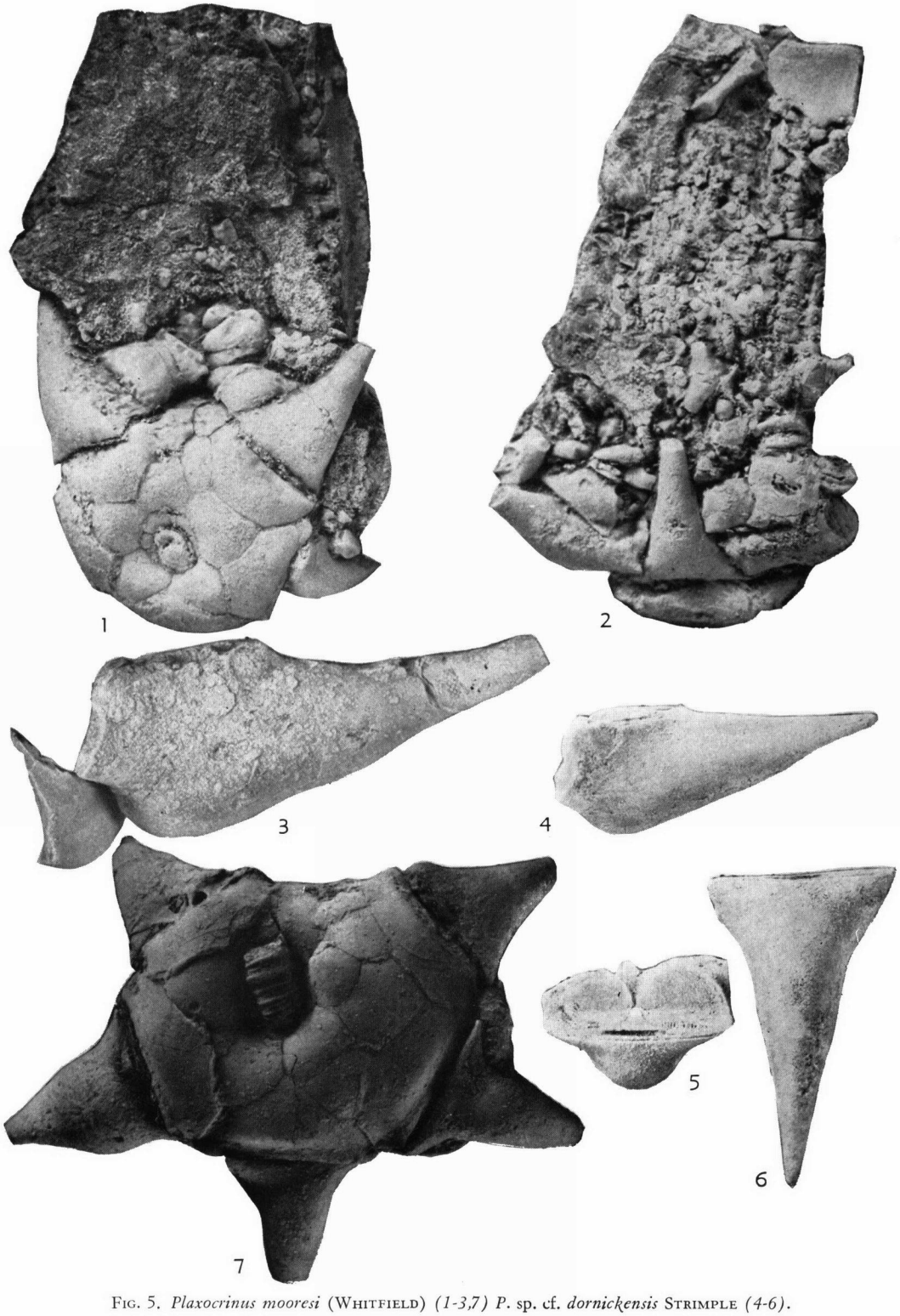

FIG. 5. *Plaxocrinus mooresi* (WHITFIELD) *(1-3,7) P.* sp. cf. *dornickensis* STRIMPLE *(4-6).*
(Continued on facing page.)

radials when arms are fully extended. When the arms are closed, spinose primibrachs project upward and together with long slender spines of other arm axillaries and spinose umbrella at the summit of anal sac, produce formidable array of spines.

One hypotype in the MORNINGSTAR collection is a small partially preserved crown (9789) with a total length of 49 mm., which was prepared with the aid of an Airbrasive machine and Vibratool to show some interesting features. The lower portion of the left half of the right posterior arm and the right half of the left posterior arm are composed of broad elements which are joined by projection and socket over the uppermost (X_2) anal plate. Some of the lower brachials interlock (biserial arrangement). A second bifurcation takes place at the fifth secundibrach in one arm and the axillary is spinose, albeit not as a large spine. Subsequent brachials are small, short and quadrangular. About 3 large, flat spines are distinguishable at the summit. The width of the crown and the size of individual terminating spines at the summit indicates a relatively small, umbrella-like termination of the anal sac.

The stem is relatively large, round, and is composed of alternatingly expanded segments.

Disarticulated ossicles from shale below the massive beds of the Pumpkin Creek Limestone were sorted long before the material from Ohio was studied by me, and the large, spinose primibrachs were found to be almost identical with those from Carbon Hill, Hocking County, Ohio. As noted previously, a dorsal cup recently has been found which is closer to *Plaxocrinus dornickensis* than to *P. mooresi.*

REMARKS.—*Plaxocrinus mooresi* is closely comparable to *P. dornickensis,* although the latter species has a smoother outline in that the basals are not tumid and no notches occur between radials at the summit of the cup. In *P. mooresi* the surface of the radial plates projects into a notched area between the upper articulating facets. The primibrachs of *P. dornickensis* typically do not develop quite so prominent a bulge as those of *P. mooresi,* although specimens from lower in the horizon do have the prominent bulge.

One small cup, collected by MOORES, out of 8 hypotypes of *P. mooresi,* has attained an advanced arrangement of anal plates, i.e., the radianal has lost contact with the right posterior basal.

TYPES.—Here designated lectoholotype no. 34232 and supporting specimens (spines) nos. 34231 and 34233, deposited in Department of Geology, University of California, Berkeley. Hypotypes nos. 9787, 15205, 9789, 24645, 24526, 24527 and 24528, deposited Orton Museum, State University of Ohio.

OCCURRENCE.—Carbon Hill, Hocking County, Ohio, probably McArthur Limestone, early Desmoinesian, Pennsylvanian.

ILLUSTRATIONS.—Figure 4,*3-7,11-15*; Figure 5,*1-3,7.*——Fig. 4,*5-7.* Lectoparatype (UC 34231), spinose first primibrach viewed from side, above, and end, ×1.8.——Fig. 4,*3-4,15.* Hypotype (OM 24528), isolated basal plate from below (*3*) and oblique view (*4*) from distal end showing irregular topography of suture faces, ×3; oblique view of isolated radial plate (*15*) showing irregular ridges along perimeter of lateral face, ×1.8.——Fig. 4,*11-14.* Lectoholotype (UC 34232), dorsal cup viewed from anterior (summit down) and posterior sides, summit, and base, ×1.8.——Fig. 5,*1-2.* Hypotype (OM 9789), crown viewed from posterior and anterior sides, ×1.8.——Fig. 5,*3.* Radial plate and primibrach (OM unnumbered), shown in normal feeding position with bulbous extension of primibrach resting on outer face of radial plate, ×1.8.——Fig. 5,*7.* Unretouched photograph of crown figured by MORNINGSTAR (1922, pl. 6, fig. 7).

PLAXOCRINUS sp. cf. P. DORNICKENSIS Strimple, 1949

Figure 5,*4-6*

DESCRIPTION.—Spinose, bulged primibrachs almost identical with those of *Plaxocrinus mooresi*

1-3,7. Plaxocrinus mooresi (WHITFIELD); *1,2,* hypotype (OM 9789) oblique view of crown from posterior and anterior; *3,* hypotype (OM unnumbered) radial plate and primibrach shown in normal feeding position; *7,* unretouched photograph of crown figured by MORNINGSTAR (1922, pl. 6, fig. 7), approximately ×1.8, from McArthur Limestone, Lower Desmoinesian, Carbon Hill, Hocking County, Ohio.

4-6. Plaxocrinus sp. cf. *dornickensis* STRIMPLE (SUI 33847), hypotype primibrach viewed from side, end, and below, approximately ×1.5, from Pumpkin Creek Limestone, Lower Desmoinesian, near Lake Murray, Love County, Oklahoma.

have been referred to *P. dornickensis* with reservation because a disarticulated crown (including the dorsal cup) was recovered recently which has features more comparable to those of *P. dornickensis*. The spinose primibrachs typically associated with *P. dornickensis* are not so protruded as specimens under consideration here. The bulged spines in Oklahoma are from a shale horizon, low in the Pumpkin Creek Limestone and the less protruded spines are from thin shale partings in the upper limestone facies of the formation. The specimens of *P. mooresi* from Ohio are embedded in an impure limestone, so the difference between bulged and more streamlined primibrachs is not due to facies change.

The function of the bulge in the lower portion of the primibrach is to provide a stop resting on the lateral surface of the radial plate when the arms are extended in feeding. The degree of protrusion is therefore related to the angle of the outer surface of the radial plate.

The present study was finished and the plates prepared prior to discovery of the dorsal cup associated with the large, bulged, spinose primibrachs.

SPECIMENS.—Deposited in Department of Geology, University of Iowa, Iowa City, nos. SUI 12328 to 12333, inclusive.

OCCURRENCE.—About 12-foot shale unit below the ridge formed by some 40 feet of limestone, Pumpkin Creek Limestone, SW¼ SW¼ SW¼ section 14, T. 6 S., R. 2 E., Love County, Oklahoma.

ILLUSTRATIONS.—Figure 5,*4-6*. Primibrach (SUI 33847), viewed from side, end, and below, ×1.5.

Family ERISOCRINIDAE S. A. Miller, 1889

Genus GRAFFHAMICRINUS Strimple, 1961

GRAFFHAMICRINUS SOMERSI (Whitfield), 1882

Figure 4,*8-10*

DESCRIPTION.—This species is based on a single specimen. No additional specimens have been found in material borrowed from Orton Museum. The drawing of the specimen presented by WHITFIELD is fairly accurate. Dorsal cup is low, truncate bowl-shaped, with deep basal concavity. There are five small down-flared infrabasals. Five large basals form most of walls of basal concavity and basal plane. They do not participate appreciably in lateral sides of cup. Radials are wide, forming sides of cup and curving into basal plane; groove formed beyond outer ligament area is accentuated by rim near summit of radials. Outer ligament ridge, well-defined outer ligament furrow, and pronounced transverse ridge present. Oblique furrows short and muscle areas of limited scope; apparently no inner muscle notch present. Anal plate broad, inclined slightly inward at cup summit and marked above by single, large, quadrangular-shaped muscle scar.

The entire surface of the cup covered by large, irregular tubercles which coalesce in places. Sutures between plates rest in V-shaped grooves.

Measurements (in millimeters) of Holotype of Graffhamicrinus somersi.

[* Measurements taken along surface curvature]

Height of cup to transverse ridge	5.0
Width of cup	17.3
Width of infrabasal circlet	3.2
Length of *DE* basal (left posterior)	7.3*
Width of *DE* basal (left posterior)	5.6*
Length of interbasal suture	3.5*
Width of *A* radial (anterior)	10.5*
Length of *A* radial (anterior) to transverse ridge	7.0*
Length of *A* radial (anterior) to outer lip	4.3*
Length of interradial suture	3.1*
Length of radial articulating facet-overall	3.7
Length of radial articulating facet-from transverse ridge	2.4
Length of anal X	4.4*
Width of anal X	2.8
Depth of basal concavity	2.3

REMARKS.—*Graffhamicrinus somersi* is distinguished from other species by the shallow nature of the cup and the distinctive ornamentation which is comprised of large, irregularly elongated tubercles which coalesce at the summit of the cup to form a rim. The short anal plate with a single facet above serves to distinguish it from the diphuicrinid stock which has a long narrow anal plate with two facets.

The species *Graffhamicrinus somersi* was referred to *Delocrinus* by MOORE & PLUMMER (1940) and assigned to *Graffhamicrinus* by STRIMPLE (1961).

LECTOTYPE.—Deposited in Department of Geology, University of California, Berkeley, no. 1349/34227.

OCCURRENCE.—Carbon Hill, Hocking County, Ohio, probably McArthur Limestone, lower Desmoinesian, Pennsylvanian.

ILLUSTRATIONS. — Figure 4,*8-10*.——Holotype (UC 34227), dorsal cup viewed from above, posterior side and from below, ×1.8.

GRAFFHAMICRINUS CONSPICUUS Strimple, new species
Figure 4,*1-2*

DESCRIPTION.—This species is based on a crown and dorsal cup with one or two primibrachs attached. The dorsal cup is low, wide, truncate bowl-shaped with wide deep basal concavity. Five infrabasals small, slightly down-flared and mostly covered by small round columnal attachment scar. Five basals large, forming sides of basal concavity and basal plane of cup, flexing upward with distal ends visible in side view of cup. Five radials wide, forming lateral walls of cup with only proximal tips entering basal plane. Single broad anal plate present with one facet above. Entire surface of cup, except for proximal sides of basal depression covered by small, sharp, widely spaced nodes. Sutures not impressed. First primibrachs low, axillary, with tumid but not spinose distal portion. Widely spaced small nodes cover primibrachs and some proximal brachials but are absent on upper arms. Arms biserial, rather broad, with flattened exteriors and sharply differentiated lateral sides. Each brachial bears a pinnule.

Measurements (in millimeters) of Holotype of Graffhamicrinus conspicuus.

[* Measurements taken along surface curvature]

Height of cup (to transverse ridge)	4.8
Width of cup	17.5[a]
Width of infrabasal circlet	4.0
Length of *DE* basal (left posterior)	8.2*
Width of *DE* basal (left posterior)	6.5*
Length of interbasal suture	4.2*
Width of *A* radial (anterior)	11.1*
Length of *A* radial (anterior) to outer lip	4.9
Length of interradial suture	3.1*
Length of anal X (paratype)	4.2*
Width of anal X (paratype)	3.7
Depth of basal concavity	2.5

[a]—Mildly distorted

REMARKS.—*Graffhamicrinus conspicuus* is readily distinguished from the associated *G. somersi* in having a more pronounced basal invagination, as well as distinctively different surface ornamentation. A few widely spaced, sharp nodes mark the surface of *G. conspicuus* and there is no impression of the sutures, whereas in *G. somersi* large tubercles mark the surface and the sutures are in V-shaped grooves.

TYPES.—Holotype and paratype no. 15781, Orton Museum, State University of Ohio, Columbus, Ohio.

OCCURRENCE.—Carbon Hill, Hocking County, Ohio, probably McArthur Limestone, lower Desmoinesian, Pennsylvanian.

ILLUSTRATIONS.—Figure 4,*1-2*.——Holotype (OM 15781), dorsal cup viewed from below and side view of upper arms, ×1.6.

REFERENCES

(See consolidated list following Part 6.)

PART 4

TWO UPPER DEVONIAN CRINOIDS

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[1] The University of Iowa, Iowa City, and [2] Riceville, Iowa

ABSTRACT

Crinoids from the Shellrock Formation (Upper Devonian) near Mason City in central northern Iowa which BELANSKI (1928) named *Bactrocrinus westoni* and *Nassoviocrinus goldringae* are redescribed on the basis of new finds. The first, designated as the type of a new genus dedicated to BELANSKI, is characterized by extremely tall slender basals, the peculiarity of having a variable number of small extra plates intercalated between the basal and radial circlets, very long pinnulate arms, and unusually elongate, narrowly cylindrical anal sac. Arm structure and nature of anal plates support transfer of BELANSKI's second species from *Nassoviocrinus* to *Quantoxocrinus*.

INTRODUCTION

A small colony of crinoids discovered in the spring of 1968 by the junior author is composed entirely of the form described by BELANSKI as *Bactrocrinus westoni,* based on several incomplete dorsal cups. Numerous well preserved crowns have been recovered and prepared with the aid of abrasion with an Airbrasive Machine. In the field, the only clue to the colony was the preservation of long, unbroken segments of stems. The rock of the horizon is typically composed almost exclusively of fragmented ossicles of crinoids, indicative of turbulent conditions. Some turbulence existed at the time the colony died because only one or two crowns are attached to the column, or for that matter to the infrabasal circlet. The infrabasal plates showed a tendency to fuse and apparently also fused with the proximal columnals. It is even possible that the crinoids could have broken free from the stem and infrabasal circlet, and attained an eleutherozoic status. Specialization, probably in response to some ecologic or morphologic impetus, is reflected by the addition of extra plates between the radial and basal circlets. The unusually long anal tube is probably also a responsive development.

The species *westoni* does not belong to the genus *Bactrocrinites* (=*Bactrocrinus*) and is assigned here to *Belanskicrinus* STRIMPLE & LEVORSON, new genus.

In the course of investigation it was found that *Nassoviocrinus goldringae* BELANSKI (1928, p. 179) from the Mason City Member, is atypical. It is assigned here as *Quantoxocrinus goldringae* (Belanksi), STRIMPLE & LEVORSON, new combination.

SYSTEMATIC PALEONTOLOGY

BELANSKICRINUS Strimple & Levorson, new genus

TYPE SPECIES.—*Bactrocrinus westoni* BELANSKI, 1928, p. 177. Range.—Upper Devonian; N. Am. (Iowa).

DIAGNOSIS.—Crown elongate, expanded, arms not opposed. Dorsal cup tall and slender, composed of 5 prominent upflared, partially fused infrabasals, 5 very tall slender basals, and 5 small short radials with articular facets narrower than plate width; one or more small plates may be, and commonly are interposed between the basal and radial circlets; 3 anal plates in normal (primitive) arrangement, radianal pentagonal in outline. Anal tube exceptionally long, slender, composed of series of polygonal structures. Arms 10, long, slender, uniserial, with well-rounded exteriors, branching on primibrach *4* or *5,* each nonaxillary brachial bearing pinnules on alternate sides. Stem moderately large, round, tapering rapidly beneath calyx for a short distance where it is composed of thin columnals, thereafter without appreciable taper and with longer columnals.

REMARKS.—One of the oddities of *Belanskicrinus* is the loss of attachment between the basal plates and the infrabasal plates so that the complete dorsal cup is seldom preserved. The infrabasal circlet is firmly attached to the proximal segments of the stem.

The addition of a circlet of plates between basals and radials is unusual, but has been observed in an entirely unrelated form named *Acrocrinus primitivus* by LAUDON & BEANE (1937, p. 252) from the Hampton Formation, Kinderhookian. Now defined as belonging to the genus *Protacrocrinus* MOORE & STRIMPLE (1969, p. 38), this species has been considered to be the progenitor of other acrocrinids.

The ancestor of *Belanskicrinus* should have at least six primibrachs in some arms and elongated basal plates. *Lasiocrinus* KIRK (1914) appears to be one of the few Devonian genera with the required characteristics. It differs from *Belanskicrinus* in having a quadrangular radianal with the right tube plate not in contact with it; also the arms are nonpinnulate. In *Lasiocrinus* the arms branch many times in bilateral heterotomy which probably leads to ultimate development of pinnules.

Both *Belanskicrinus* and *Lasiocrinus* have long, slender anal tubes, composed below of large plates and above by several parallel vertical rows of small hexagonal plates. *Lasiocrinus* is reported to have prominent spines at the summit of the anal sac, but no such spines are seen in *Belanskicrinus.*

The arms of Silurian forms like *Bactrocrinites oklahomaensis* STRIMPLE (1952) are not known but the elongated basal plates indicate a possible affinity to *Belanskicrinus.* The radianal of this crinoid is quadrangular, as in *Lasiocrinus.* We judge that the primitive stage among these forms was characterized by a quadrangular radianal and that the right tube plate progressively mi-

grated into the cup so as eventually to make full contact with the radianal on a fifth side, the latter plate developing a pentagonal shape.

The genus *Cradeocrinus* GOLDRING (1923) appears to be closely related to *Belanskicrinus* but possesses only three (rarely four) primibrachs, a condition considered to be more advanced than in our new genus, but it bears ramules on every third or fourth secundibrach, which is more primitive. Each nonaxillary brachial of *Belanskicrinus* bears a pinnule. *Cradeocrinus* is reported to have a pentagonal radianal, in common with *Belanskicrinus*.

BELANSKICRINUS WESTONI (Belanski), Strimple & Levorson, new combination

Figures 3,5; 6; 7,*1-5*

DESCRIPTION.—Same as for the genus.

TYPES.—Holotype, B1675, paratypes B1980, B1982, B1861, collected by C. H. BELANSKI, hypotypes SUI 33410 (3 specimens), 33411, and 33412, collected by C. O. LEVORSON, reposited in Department of Geology Collections, The University of Iowa, Iowa City.

OCCURRENCE.—Specimens collected by BELANSKI are from the "Trigonotreta zone," "Bactrocrinus zonule," Mason City Member, Shellrock Formation, Upper Devonian in NE¼, SW¼, sec. 14, T. 95 N., R. 18 W., opposite mouth of Lime Creek, abandoned quarry in NW¼, NW¼, sec. 17, T. 96 N., R. 18 W., and abandoned quarry in NE¼, SW¼, sec. 10, T. 95 N., R. 18 W., near Rockford, all in Floyd County, Iowa.

Materials collected by C. O. LEVORSON were obtained from the north wall of the Williams quarry, NW¼, SW¼, sec. 28, T. 96 N., R. 18 W., Floyd County, Iowa.

ILLUSTRATIONS.—Figure 3,*5;* Figure 6; Figure 7, *1-5*.——Fig. 3,*5*. Paratype (CHB 1675) with infrabasals and basals missing, viewed from *B* ray, approximately ×2.——Fig. 6. Camera lucida drawing, A-ray view of hypotype crown (SUI 33851) showing circlet of supernumerary plates (intercalaries) below radial circlet, approximately ×4.2.——Fig. 7,*1*. *E*-ray view of hypotype (SUI 33412) with infrabasals and column attached, approximately ×1.5.——Fig. 7,*2*. *D*-ray view of hypotype crown (SUI 33411), approximately ×1.5.——Fig. 7,*3*. *CD* interray view of cup with proximal segments of arms attached (SUI 33412-2), approximately ×1.4.——Fig. 7,*4*. Side view of hypotype (SUI 33412-1) crown showing long dendrocrinid type anal sac, approximately ×1.5.——Fig. 7,*5*. Side view of hypotype (SUI 33412-3), approximately ×1.5.

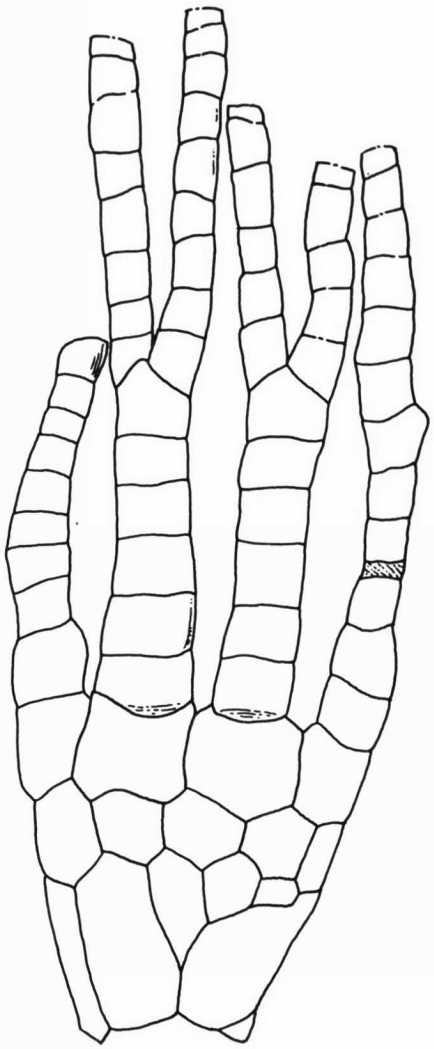

FIG. 6. *Belanskicrinus westoni* (BELANSKI), camera lucida drawing of hypotype crown (SUI 33851), *A*-ray view showing circlet of intercalaries below radial circlet, approximately ×3.4.

QUANTOXOCRINUS GOLDRINGAE (Belanski), Strimple & Levorson, new combination

Figure 3,*3,4*

DESCRIPTION.—The species named *Nassoviocrinus goldringae* by BELANSKI (1928) is considered to be atypical of the genus *Nassoviocrinus* (type species, *N. pachydactylus*) in that the radianal is pentagonal in *goldringae* but is typically quadrangular in species of *Nassoviocrinus*. This

signifies that a right tube plate is in contact with the radianal in *goldringae,* which condition we believe to be more advanced than in forms having the right tube plate well removed from contact with the radianal, or entirely missing as an identifiable calyx element.

The genus *Quantoxocrinus* WEBBY (1965) (type species, *Q. ussheri*) has all of characteristics ascribed to *goldringae* and accordingly the species is here referred to as *Quantoxocrinus goldringae.* WEBBY (1965, p. 12) made no reference to *Nassoviocrinus,* although the genera typically have similar dorsal cups, depressed areas at the corners of the cup plates, pinnulate arms, and pentalobate proximal columnals.

Other genera considered by WEBBY (1965, p. 12-13) as bearing similarities to *Quantoxocrinus* are *Iteacrinus* GOLDRING, *Decadocrinus* WACHSMUTH & SPRINGER, *Denariocrinus* SCHMIDT, and *Rhadinocrinus* JAEKEL. *Iteacrinus* (type species, *I. flagellum*) and *Rhadinocrinus* (type species, *R. rhenanus*) are readily separable in having ramules at intervals, rather than pinnules as in *Quantoxocrinus.* Both *Decadocrinus* (type species, *Poteriocrinus scalaris*) and *Denariocrinus* (type species, *D. ferula*) are differentiated from *Quantoxocrinus* in having a primary bifurcation on the second primibrach and apparently they have round proximal columnals.

TYPES.—Holotype, B1981, B1983, collected by C. H. BELANSKI, deposited in collections of the Department of Geology, The University of Iowa, Iowa City.

OCCURRENCE.—"Trigonotreta zone," "Nassoviocrinus zonule," Mason City Member, Shellrock Formation, Upper Devonian in NW¼, NW¼, sec. 17, T. 96 N., R. 18 W., abandoned quarry, southern part of Nora Springs, Floyd County, Iowa.

ILLUSTRATIONS.—Figure 3,*3,4.*——*3.* Holotype (CHB1981) partial crown viewed from *AB* interray.——*4.* Paratype (CHB1983) partial crown, left specimen, viewed from *AB* interray. Both approximately ×2.

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(See consolidated list following Part 6.)

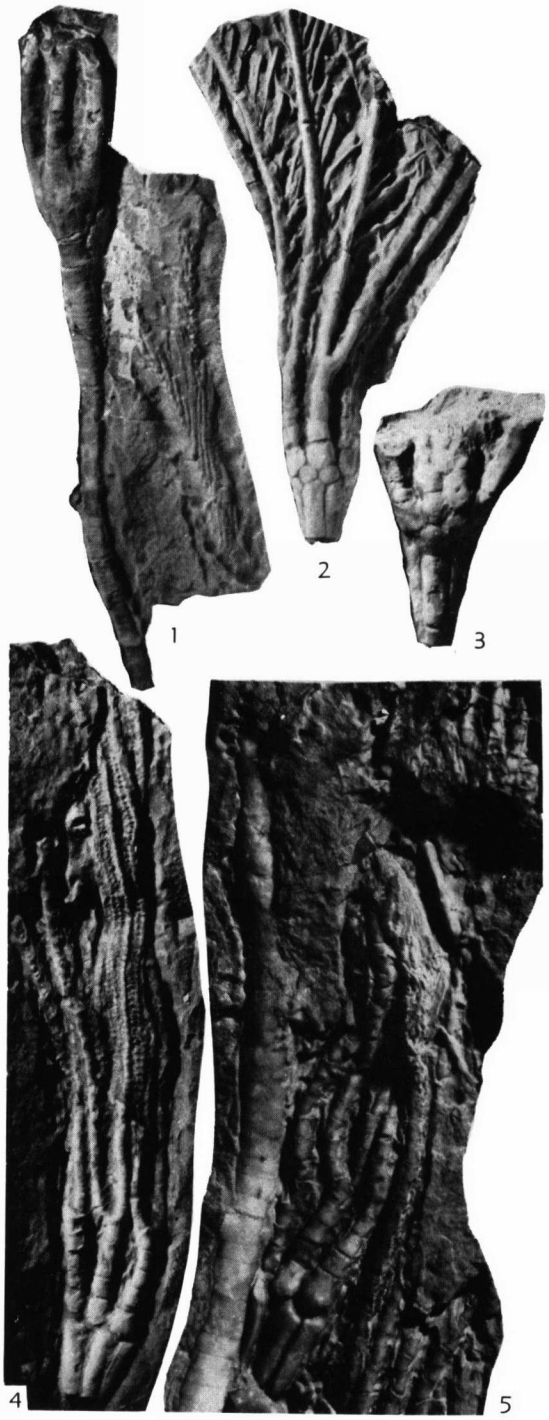

FIG. 7. *Belanskicrinus westoni* (BELANSKI), Upper Devonian, near Nora Springs, Floyd County, Iowa.——*1.* *E*-ray view partial crown hypotype (SUI 33412) with infrabasals and column attached.——*2.* *D*-ray view of hypotype crown (SUI 33411).——*3.* *CD*-interray view of hypotype cup with proximal portion of arms attached (SUI 33412-2).——*4.* Side view of hypotype crown showing long dendrocrinid type anal sac (SUI 33412-1).——*5.* Side view of hypotype crown (SUI 33412-3). All figures approximately X1.5.

PART 5

NEW CRINOID FROM THE GILMORE CITY FORMATION, LOWER MISSISSIPPIAN OF IOWA

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ABSTRACT

A new Lower Mississippian pachylocrinid with cone-shaped dorsal cup and impressed plate angles is described. Arms commonly branch twice. They are composed of uniserial pinnule-bearing brachials. A very long reflexed anal tube has thin small polygonal plates with lateral slits.

INTRODUCTION

The comprehensive study of crinoids from the Gilmore City Formation made by L. R. LAUDON (1933) covered almost every species ever found in that horizon. It was therefore of considerable surprise to us when a form appeared in the collections being made currently which did not agree with any known species. Subsequent investigation led to the conclusion that no suitable genus existed for its inclusion. The name *Sostronocrinus superbus* n. gen., n. sp. is proposed herein.

SYSTEMATIC PALEONTOLOGY

Family PACHYLOCRINIDAE Kirk, 1942

Genus SOSTRONOCRINUS Strimple & McGinnis, new genus

TYPE SPECIES. — *Sostronocrinus superbus* STRIMPLE & MCGINNIS, n. sp.

DESCRIPTION.—Crown elongate, expanded with arms not apposed. Dorsal cup cone-shaped, angles of cup plates impressed, infrabasals visible in side view. There are 5 infrabasals, 5 basals, 5 radials and 3 anal plates. Expansion of the cup is even from base to the summit. First branching of the arms is normally with primibrach *2* but may be with primibrach *3*. A second higher branching usually occurs with secundibrach *7* to *11*. The arms have well rounded exteriors. Brachials are lightly cuneate, each bearing a pinnule and each medially constricted. The anal tube is very long, reflexed, and composed of series of small, thin, polygonal plates. The tube plates have slits along the lateral sides and many have a median ridge. The column is mildly pentagonal near the cup.

RELATIONSHIP.—The progenitor of *Sostronocrinus* is somewhat obscure but is probably a form like *Iteacrinus robustus* GOLDRING (1923, p. 347). Because three primibrachs are retained in some arms of *Sostronocrinus superbus,* its progenitor should not have less than three and could very well have more than three primibrachs. The addition of arms is a normal evolutionary condition but in this instance both have more than ten arms. Pits are prevalent at angles formed at corners of the basal and radial circlets in both forms.

Evolution through reduction of the number of primibrachs to two and addition of arms apparently leads directly to Osagian *Pachylocrinus.* VAN SANT (1964, p. 87) has discussed the chronological development of the genus and a description was promised, but not given. If the description of *Pachylocrinus aequalis* (HALL), type species of the genus, is considered also to constitute a generic description, then the infrabasals are known to be subhorizontal or slightly downflared and confined to the basal concavity, and the first branching of the arms is with primibrach *2* in all rays. *Pachylocrinus manus* (MILLER & GURLEY), also discussed by VAN SANT, has the first branching with primibrach *1,* which is an atypical bifurcation point. The species is a monotypic form and might represent a case of *portentum* wherein the characteristics reflect a condition attained by a descendant, in this case a form of the Pennsylvanian genus *Plummericrinus,* wherein the arms usually branch on primibrach *1* in all rays.

The pitlike depressions at angles between basal and radial circlets and the general contour of the cup of *Pachylocrinus aequalis* is very similar to that of *Sostronocrinus superbus,* but the latter shows distal ends of the infrabasals visible

in side view of the cup, the arms branch only twice, and primibrach *2* or *3* may be axillary. The infrabasals of *Pachylocrinus aequalis* are not visible in side view, the arms typically branch more than twice, and primibrach *2* is axillary in all arms.

The generic name is from the Greek *sostron,* meaning reward, with reference to being a reward for diligent search.

Occurrence.—Lower Mississippian (Kinderhookian): Iowa, USA.

SOSTRONOCRINUS SUPERBUS Strimple & McGinnis, new species

Figure 8,*1-3*

Description.—Same as given for the genus except for additional note of the acute depressions at angles of the cup plates. Actually these are related to three broad ridges which pass from plate to plate. Relative measurements of various cup elements may be found to have specific value. All specimens observed to date have a brown or light red coloration.

Measurements of Holotype of Sostronocrinus superbus *(in millimeters).*

Length of crown (as preserved)	28.4
Length of anal tube (complete)	24.6
Height of dorsal cup	3.7
Width of dorsal cup (average)	5.0
Height of infrabasal circlet	0.9
Length of basal plate (*D-E* ray)	2.0
Width of basal plate (*D-E* ray)	1.8
Length of radial plate (*A* ray)	1.5
Width of radial plate (*A* ray)	2.2
Diameter of proximal columnal	1.6

Types.—Holotype (SUI 32919), and paratypes SUI 32920, 32921, collected by M. R. McGinnis, in the Repository, Department of Geology, The University of Iowa, Iowa City.

Occurrence.—Gilmore City Formation, Kinderhookian, Mississippian; Gilmore City Quarries in SW sec. 25, T. 92 N., R. 31 W., Pocahontas County, Iowa.

Illustrations.—Figure 8,*1-3.*——*1,3.* Holotype (SUI 32920) from *CD* and from *A* ray.——*2.* Paratype (SUI 32921) from *B* ray. All figures approximately ×2.5.

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(See consolidated list following Part 6.)

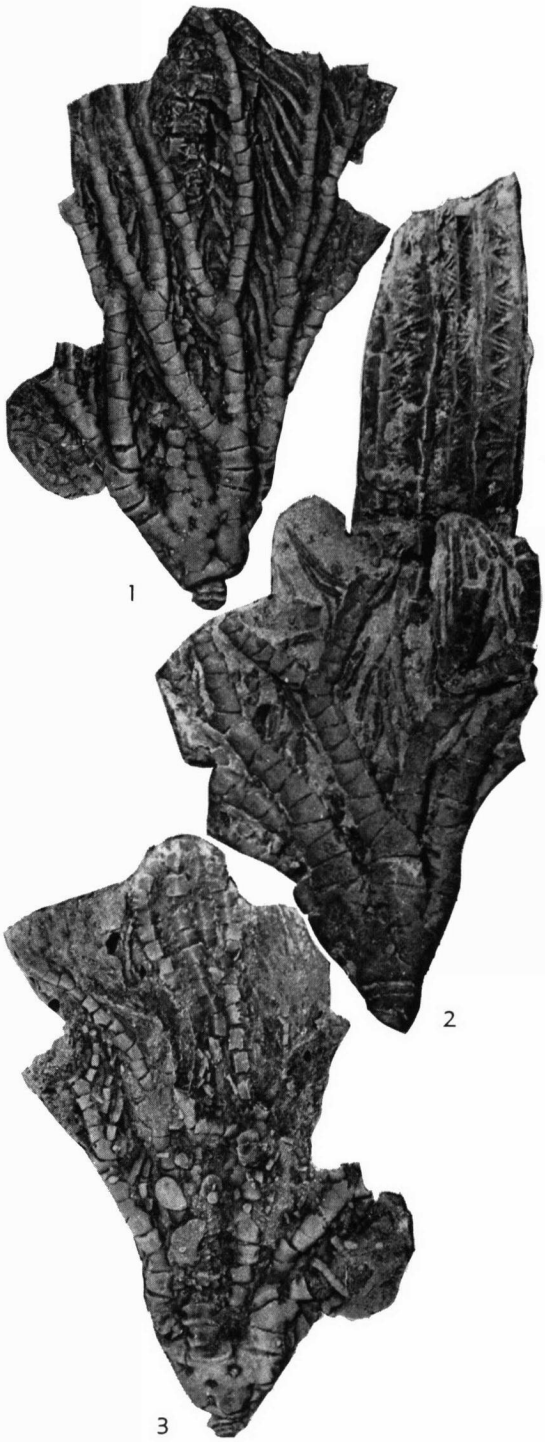

Fig. 8. *Sostronocrinus superbus* Strimple & McGinnis, Gilmore City Formation, Kinderhookian, Lower Mississippian, near Gilmore City, Pocahontas County, Iowa.——*1,2.* Holotype (SUI 32920) from *CD* and *A* ray.——*3.* Paratype (SUI 32921) from *B* ray. All figures approximately ×2.5.

PART 6
NEW ERISOCRINID FROM NEBRASKA

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ABSTRACT

Description of *Tholiacrinus decapodos* STRIMPLE & PRIEST, n. sp., from the Oread Formation of eastern Nebraska discloses strategically placed nodes.

We advance the idea of a decapod being formed by "elbow-like" knobs at mid-length of the arms. The supposition is that the habitat of the animal was the ocean floor rather than being projected above the floor at top of a long stem.

INTRODUCTION

An unusual development in *Tholiacrinus decapodos* STRIMPLE & PRIEST, n. sp., consists of a series of low nodes on the lower portion of each arm and nodes near the summit of the radial plates. These warrant special scrutiny from the standpoint of their possible significance as adaptive features. Because nodes are common on plates of many crinoids, workers have tended to consider them as nonfunctional. Opposed to this, we believe that usually they have a purpose, albeit obscure on occasion. In studying the new species described here, we visualize living position of the crinoid with its crown resting on the base of the cup on a soft sea bottom. The stem, if more than a remnant was present, would be curved into a subhorizontal position and more or less embedded in the mud. When the arms were fully extended the knobs on the primibrachs would rest on projections near the summit of the radials. The lower portions of the arms then would be directed downward and the nodose section would rest on the mud forming a "decapod" of ten outspread props to balance the animal and possibly to offset the effects of vibrations from movements of food gathering devices which could cause the animal to sink into the mud. The upper portions of the arms and all pinnules would be directed outward or upward to provide a broad area for collecting food. This interpretation can be demonstrated mechanically with clay models.

SYSTEMATIC PALEONTOLOGY

Family ERISOCRINIDAE S.A. Miller, 1889

Genus THOLIACRINUS Strimple, 1962

TYPE SPECIES. — *Corythocrinus undulatus* STRIMPLE 1961, p. 128.

REMARKS.—*Graffhamicrinus* STRIMPLE (1961c) does not appear to differ appreciably from *Delocrinus* MILLER & GURLEY (1890), or *Tholiacrinus* from *Endelocrinus* MOORE & PLUMMER (1940), except that the surfaces of the former are ornamented by granules or pustules, or both, yet *Delocrinus* and *Endelocrinus* are smooth. *Tholiacrinus* and *Graffhamicrinus* never have a large spike-like primibrach. The significance of the ornamentation is not normally ascertained but a possible explanation has been advanced in the case of *T. decapodos* as previously discussed.

The ancestor of *Tholiacrinus* appears to be *Endelocrinus matheri* (MOORE & PLUMMER, 1938).

THOLIACRINUS DECAPODOS Strimple & Priest, new species

Figure 9,*1-4*

DESCRIPTION.—Crown moderately long and normally compact when arms are in repose. Cup low, bowl-shaped with decided basal concavity, sutures impressed. Infrabasals are downflared, small, confined to basal concavity. Basals are large, curve out of basal concavity to participate in lateral walls of cup. Radials are slightly wider than high; a slightly flattened arc is formed below the outer articulating area and is marked below by a slight rim accentuated by two nodes in mid-portion. The articulating facets fill the entire width of the radials. A single hexagonal anal plate projects well above the cup and rests on the truncated distal end of the posterior basal. First primibrachs are axillary, slightly elongated with distal end slightly protruded, but not as a spine. Subsequent laterally interlocked

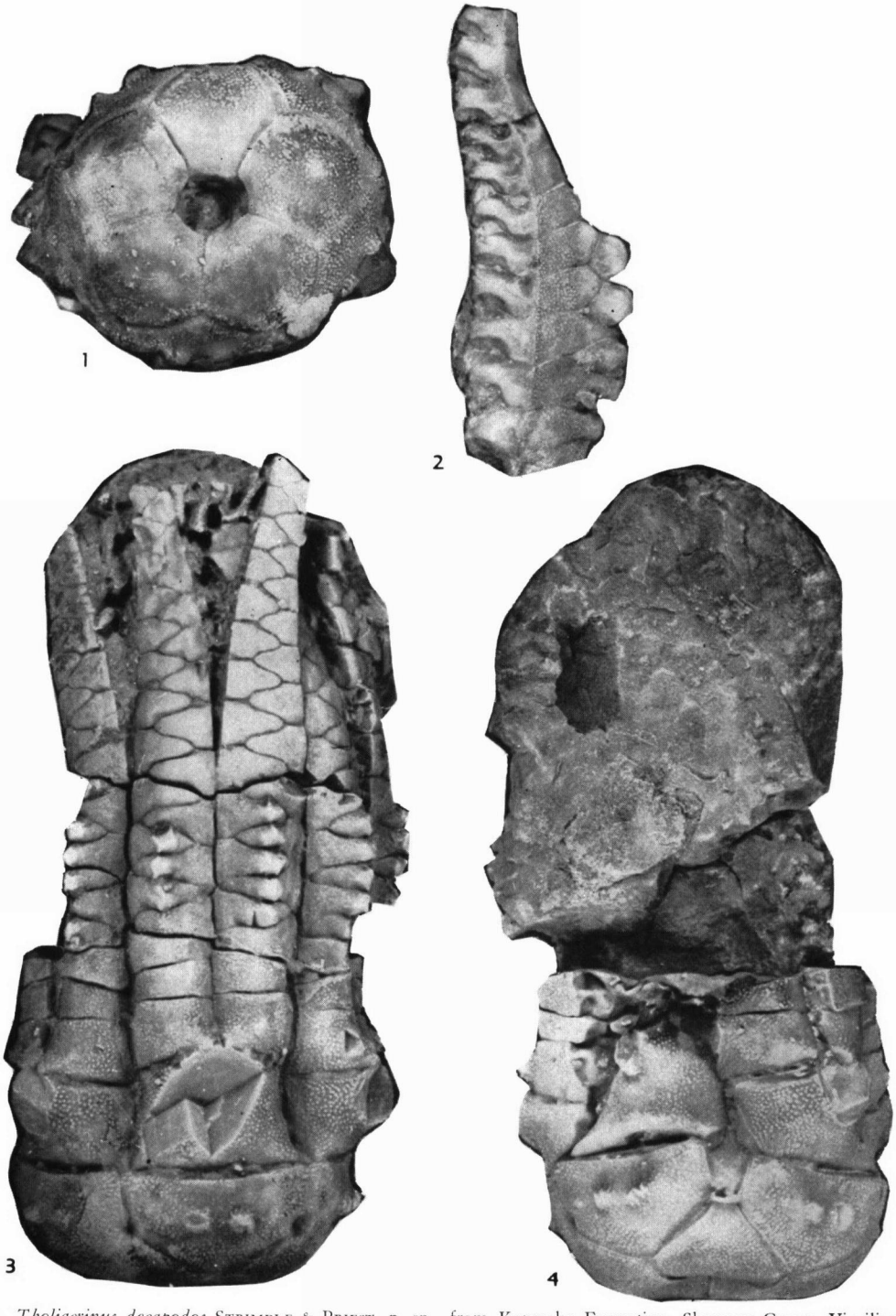

FIG. 9. *Tholiacrinus decapodos* STRIMPLE & PRIEST, n. sp., from Kanwaka Formation, Shawnee Group, Virgilian, near Plattsmouth, Cass County, Nebraska, approximately ×3.3.

1,3,4. Holotype (SUI 32167) viewed from base, anterior and posterior.

2. Paratype (SUI 32245) arm viewed from side showing pronounced nodes and protrusion of arm, and grooved lateral side.

brachials form ten biserial arms. On or about the fourth secundibrach, each arm develops a median ridge which is accentuated by a series of sharp-edged projections parallel to the median ridge. The possible meaning of these projections has already been discussed. At mid-length the arms have no projections or ornamentation of any kind; distally from this point they taper slowly to their tips.

The entire surface of the cup and lower portions of the arms are covered by granulations. The small stem is pierced by a stellate-shaped lumen. The crown of holotype is 39.5 mm. long of which 6.0 mm. is the dorsal cup and the width of dorsal cup is 16.3 mm. (maximum).

REMARKS.—Isolated radial plates and arm segments with the distinctive ornamentation of this species are readily identifiable. The combination of nodes and fine granulations is also a characteristic of *Graffhamicrinus granulosus* (MOORE & PLUMMER, 1940) and similar species but the consistent presence of two prominent nodes in upper mid-position of the radial appears to be unique for *Tholiacrinus decapodos*. *G. bispinosus* (MOORE & PLUMMER, 1940) consistently has a pair of nodes but they occur at the outer edges of the radial, near the sutures. *T. parinodosarius* (STRIMPLE, 1940) has a shallow cup and a series of nodes across the upper face of each radial plate. *T. bifidus* (MOORE & PLUMMER, 1940) and *T. rectus* (MOORE & PLUMMER, 1940) have irregular-spaced nodes and in general appear to have more shallow cups than *T. decapodos*. The arms of *T. undulatus* (STRIMPLE, 1961), the type species of *Tholiacrinus,* have no pronounced projections, such as those found in *T. decapodos*. In the arms of *T. undulatus* the secundibrach *1* interlocks with secundibrach *2* (the arms being fully biserial) as in *Graffhamicrinus* but in *T. decapodos* the segments do not fully interlock below secundibrachs *3* or *4*.

TYPES.—Holotype SUI 32167 and paratypes SUI 32168 and 32245 are deposited in Repository, Department of Geology, University of Iowa, Iowa City; collected by AMEL PRIEST.

OCCURRENCE.—Kanwaka Formation, Shawnee Group, West Lake Quarry south of Plattsmouth, Cass County, Nebraska.

ILLUSTRATIONS.—Figure 9,*1-4*.——*1,3-4*. Holotype (SUI 32167), viewed from base, anterior and posterior.——*2*. Paratype (SUI 32245), arm viewed from side showing pronounced nodes and protrusion of arm as well as decisively grooved lateral side of the arm with the pinnular articular facets barely visible at the inner edge of the arm. Unretouched photographs magnified about ×3.3.

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