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ADDITIONAL PERMIAN CRINOIDS FROM SOUTHERN NEVADA

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ABSTRACT

A total of 37 genera and 47 species of Lower Permian crinoids are now known from Battleship Wash, Arrow Canyon Range, southern Nevada, making this fauna one of the largest known Paleozoic crinoid faunas from a single locality. New taxa include a camerate crinoid and a disparid inadunate; one new genus and species of cladid inadunate, and 11 new species of other cladids are described, of which 5 are new species belonging to genera not previously recorded from the site. Additional new species of *Moapacrinus, Elibatocrinus, Perimestocrinus, Aesiocrinus,* and *Stellarocrinus* are also described. Genera previously unknown but represented by specimens too imperfect to serve as holotypes of new species include *Schedexocrinus* and *Petschoracrinus?*. Several forms listed as "genus and species unknown" clearly represent new, unusual crinoids, but are rare in the fauna and are represented by incomplete or poorly preserved specimens. Additional morphologic information is provided for most of the earlier described species and the collection now includes a total of 535 specimens of varying completeness and quality of preservation.

INTRODUCTION

During the three years since the manuscript was completed for our first report on Lower Permian crinoids from southern Nevada (LANE & WEBSTER, 1966), we have continued to collect at the crinoid site and have obtained many more specimens than were originally available; some represent new taxa. Both the quality and abundance of crinoids found during these collecting trips have declined gradually and though the locality is not exhausted, smaller and smaller returns have resulted from our efforts to obtain an adequate representation of the Battleship Wash crinoids. Therefore, we believe this is an appropriate time to make a comprehensive review of initially described taxa, and to report on several new forms. Our purpose, then, is to furnish new morphological information on many of the species reported in the previous paper, to describe new taxa found subsequent to that study, and to tabulate the relative abundance of crinoid species now known from this locality.

We have found additional specimens of all but 7 of the 28 crinoid species that were described initially, and report here on 19 of the 21 species represented by new material. Only *Aesiocrinus delicatulus* and *A. inornatus* are represented by

additional specimens that furnish no new morphological information. No new specimens of *Cibolocrinus typus, Moscovicrinus bipinnatus, Stenopecrinus? xerophilus, Utharocrinus* sp., or *Allosocrinus quinarius,* or of Species A and B of the first report, have been found and consequently these taxa are also omitted. Eighteen new species, distributed among 12 genera, one of them new, have now been discovered, bringing the total number of known crinoids from Battleship Wash to 37 genera and 47 species. This taxonomic diversity is rivalled by few other Paleozoic crinoid faunas from a single locality.

In our first report all specimens represented either flexible crinoids or poteriocrinitid inadunates. We now have representatives of monobathrid camerates and of disparid inadunates, so that five of the seven Paleozoic orders of crinoids are represented in the fauna. Only the orders Hybocrinida and Diplobathrida are lacking, and these groups are thought to have become extinct in the Silurian and Mississippian periods respectively. The only crinoids not now recorded by specimens from Battleship Wash that one could expect to find in a Permian fauna are the aberrant, small cyathocrinoids in the family Codiacrinidae. These crinoids are reasonably abundant and diversified in the Timor Permian, and we have searched carefully but unsuccessfully through acid residues in an attempt to find silicified codiacrinids.

We have already pointed out that the presence of *Synyphocrinus, Moscovicrinus,* and the timorechinid *Exocrinus* in the Battleship Wash fauna indicate faunal relationship with eastern hemisphere late Paleozoic crinoids from Russia and Timor. We can now add to this list of genera *Platycrinites, Neozeacrinus, Petschoracrinus,* and perhaps *Isoallagecrinus,* of which the first two occur in the Timor Permian and the third in Russia. Although the fourth genus has been reported only from Oklahoma, related allagecrinids are common and diversified in the Timor fauna.

EVOLUTION

New taxa described in this report allow us to make a better analysis of overall Pennsylvanian and Permian evolutionary trends among inadunate crinoids than was possible three years ago. In order to facilitate such a study we have tabulated known morphological information about Permian Timor poteriocrinoids so that we can compare the Battleship Wash crinoids with both older Pennsylvanian, and younger Permian faunas (Table 1). Our comparisons show that the

TABLE 1.—*Numerical Comparison of Morphological Features that Exhibit Evolutionary Trends among Poteriocrinoid Genera of North American Pennsylvanian, Battleship Wash, and Permian of Timor.*

Morphologic feature		Number of genera Penn.[a]	BW[b]	Timor[c]
Nature of base of cup	Convex	8	7	10
	Flat	11	6	4
	Concave	28	16	12
	Total	47	29	26
Plate on which arms first branch	0	1	2	2
	IBr_1	37	24	8
	IBr_2	4	3	1
	$>IBr_2$	0	1	0
	Total	42	30	11
Number of anal plates	0	2	1	3
	1	12	13	15
	2	6	1	1
	3	28	10	3
	Total	48	25	22
Nature of arms	Uniserial	24	23	11
	Biserial	15	6	0
	Total	39	29	11
Number of orders of branches per ray	1	1	2	2
	2	13	10	3
	3	12	8	2
	4	7	3	1
	5	4	3	3
	6	1	2	0
	Total	38	28	11
Direction of slope of radial facet	Out	26	16	16
	Horizontal	14	12	5
	In	4	1	3
	Total	44	29	24
Width of radial facet	Narrow	14	9	18
	Wide	34	21	8
	Total	48	30	26

[a] Pennsylvanian genera from North America; compiled from MOORE & PLUMMER (1938, 1940), MOORE (1939, 1940) and STRIMPLE (1961, 1962b).

[b] Battleship Wash crinoids; compiled from this report and LANE & WEBSTER (1966).

[c] Permian crinoid genera from Timor; compiled from WANNER (1916, 1923, 1937).

Nevada crinoids are intermediate between Pennsylvanian genera and Timor crinoids in the numerical importance of several morphological features, which is in accord with the relative ages of the faunas.

One of the most striking trends shown on Table 1 is the progressive decrease in proportion of genera with biserial arms. Crinoids with this advanced type of arm structure reached a climax of diversity in the Pennsylvanian but dwindled in importance during the Permian, none being known from the Timor beds, although the arms are unknown for many species from the area.

Another persistent trend is the decrease in number of genera with either two or three anal plates in the cup. To what extent this trend developed by extinction of forms with two or three anal plates, or by evolution of such types into genera with just one anal, is not known.

Although a basally concave dorsal cup is judged to be an advanced evolutionary feature among these crinoids, this characteristic is much more common among Pennsylvanian than among Permian crinoids, and in the Timor fauna genera with a convex or flat base are collectively dominant.

The fourth trend that is evident from this comparison is that while almost 70 percent of Pennsylvanian and Battleship Wash genera have wide radial facets, only 30 percent of Timor genera have a facet that fills the distal surface of the radial.

In summary, we can point out that genera with biserial arms, a concave base, and three anal plates reached a climax during Pennsylvanian time and progressively decreased in importance during the Permian Period. Genera with uniserial arms, a single anal, a flat or convex base, and narrow radial facets became increasingly dominant during the Permian. These changes can be viewed collectively as an architectural simplification of the poteriocrinoid crown during the final 120 million years of the Paleozoic Era.

There are two ways in which this overall simplification could have taken place. Permian genera with the dominant features listed above that are generally considered to be less advanced or specialized, could have evolved from older genera with morphological characters that are usually judged to be more advanced, or more specialized. This might be called evolutionary simplification. The other alternative is that many Pennsylvanian genera with specialized features like a concave base, or biserial arms became extinct, and many Permian forms evolved from more generalized Pennsylvanian stocks that were conservative in retaining simplified morphological features. Both of these processes have been called on at one time or another to explain the evolutionary history of various groups of animals, and perhaps both played a part in the final evolutionary phases of the poteriocrinoids. If so, the relative importance of the two processes is not known, and evaluation of this problem must await more detailed phylogenetic studies at the generic and familial levels of late Paleozoic poteriocrinoids.

DIVERSITY AND ABUNDANCE OF BATTLESHIP WASH CRINOIDS

The crinoids reported here were collected during a number of field trips to Nevada, and we can conveniently divide the specimens into two samples: those collected prior to submittal of the first manuscript on the fauna, and those collected subsequently, but prior to preparation of this report. During the initial collection period, from April to November, 1964, when the fauna was first discovered and exploited, we obtained a total of 236 specimens of crinoids representing 30 taxa, an average of about 8 specimens per taxon. During the past two years additional collecting has resulted in obtaining more than double the number of specimens initially available, 299 being collected during that period, so that this report is based on a total of 535 identifiable crinoids (Table 2). During the second period representatives of 38 taxa were collected, or an average of 7.9 specimens per taxon, an insignificant change in average number of specimens per taxon collected.

As would be expected, doubling the size of the sample resulted in an increase in number of taxa recognized, a relative increase of 8 taxa (30 versus 38), but an absolute increase of 17 taxa because 9 species initially discovered were represented by no additional specimens during the second sampling period.

One of the striking differences between the sample characteristics of the two collecting periods is the difference in number of species represented by a single specimen. Nine such species were found initially, and six of these are not represented by at least one additional specimen obtained sub-

TABLE 2.—*Number and Condition of Crinoid Specimens Found at Battleship Wash from April to November, 1964 (Sample 1), from April, 1965 to November, 1966 (Sample 2), and Total Number of Known Specimens.*

Genera and species	Sample 1, no. of specimens	Sample 2, no. of specimens	Condition of specimens				Total specimens
			Dorsal cups	Arms + part of cup + part of arms	Sets of arms	Crowns	
Nevadacrinus geniculatus	3	10	....	2	6	5	13
Trampidocrinus phiala	8	22	....	....	2	28	30
T. bellicus	7	15	....	....	6	16	22
Cibolocrinus typus	2	....	....	....	....	2	2
Isoallagecrinus eaglei	....	1	....	....	....	1	1
Stellarocrinus cuneatus	5	5	1	....	3	6	10
S. comptus	....	1	....	....	....	1	1
S.? sp.	....	1	....	....	....	1	1
Celonocrinus expansus	6	5	....	2	8	1	11
Species A	3	3	....	1	5	....	6
Synyphocrinus permicus	7	6	....	5	7	1	13
Agnostocrinus typus	....	1	....	....	....	1	1
Elibatocrinus elongatus	1	5	....	....	2	4	6
Moscovicrinus bipinnatus	3	....	....	....	2	1	3
Moapacrinus rotundatus	72	65	20	30	85	2	137
M. inornatus	....	13	2	3	5	3	13
Texacrinus distortus	....	3	....	....	1	2	3
Exocrinus moorei	10	17	....	7	8	12	27
Stuartwellercrinus corbatoi	7	9	2	8	2	4	16
Species B	....	1	....	1	....	....	1
Petschoracrinus? sp.	....	2	2	....	....	....	2
Parethelocrinus rectilatus	2	1	....	2	....	1	3
Species C	....	1	....	1	....	....	1
Arroyocrinus popenoei	40[a]	43	1	4	73	5	83
Erisocrinus longwelli	25[a]	34	4	23	29	3	59
Delocrinus vastus	9[a]	12	....	7	14	....	21
Endelocrinus torus	....	1	....	1	....	....	1
E. sp.	....	1	....	....	....	1	1
Graphiocrinus scopulus	2	1	....	3	....	....	3
Phanocrinus? insolitus	....	1	....	....	....	1	1
Aatocrinus permicus	....	1	1	....	....	....	1
Neozeacrinus wanneri	....	2	....	....	....	2	2
N. coronulus	....	1	....	....	....	1	1
Plaxocrinus piutae	3	5	1	1	6	....	8
P. sp.[b]	1	....	....	1	....	....	1
Perimestocrinus nevadensis	1	1	....	....	....	2	2
P. oasis	....	1	....	1	....	....	1
Stenopecrinus? xerophilus	4	....	....	4	....	....	4
Utharocrinus sp.	1	....	....	1	....	....	1
Schedexocrinus sp.	1	1	....	2	....	....	2
Allosocrinus quinarius	1	....	....	1	....	....	1
Aesiocrinus delicatulus	1	....	....	....	....	1	1
A. inornatus	2	2	1	2	....	1	4
A. nodosus	....	1	....	....	....	1	1
Polusocrinus amplus	7	4	1	3	6	1	11
Species A, 1966	1	....	....	1	....	....	1
Species B, 1966	1	....	....	....	1	....	1
Total	236	299	36	118	271	110	535

[a] Estimated.
[b] Assigned to *P. piutae* in first report (1966).

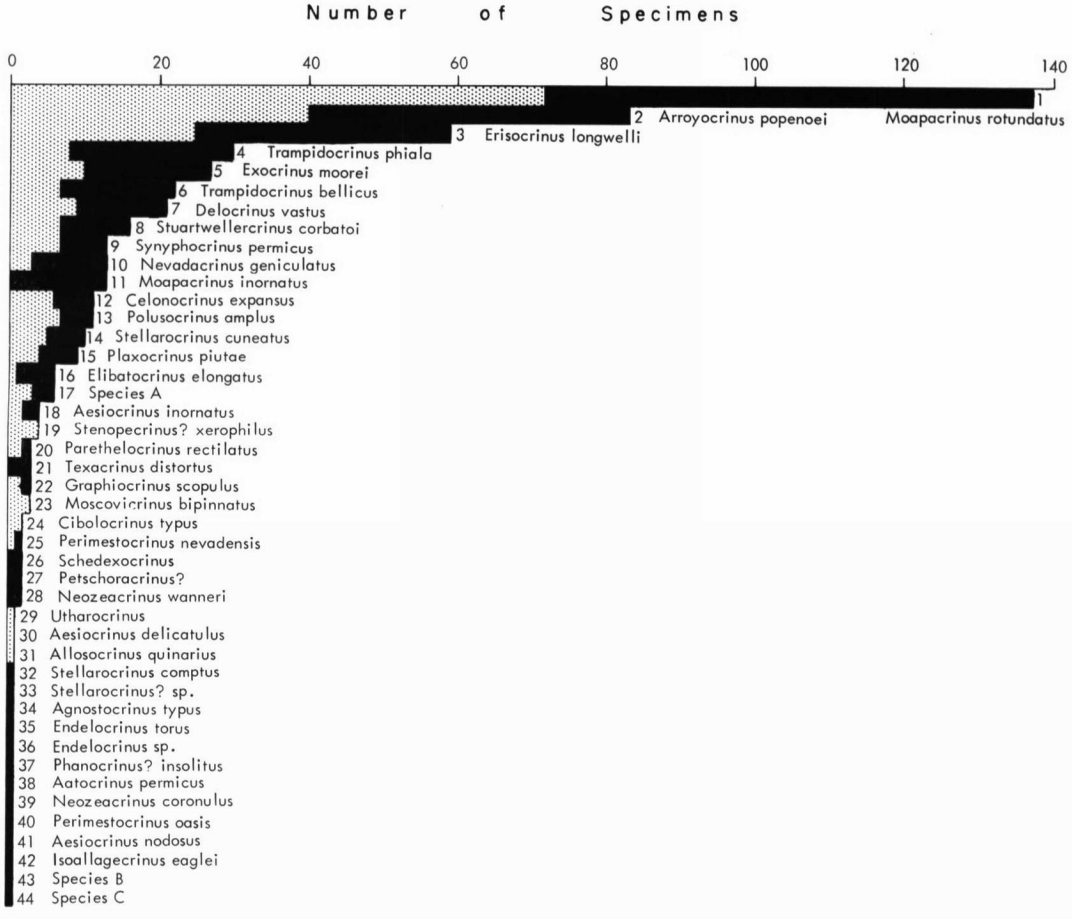

FIG. 1. Numbers of specimens of crinoid species found at Battleship Wash. Stippled area represents specimens found from April to November, 1964 (Sample 1); black area specimens found from April, 1965, to November, 1966 (Sample 2). The top of each column records total number of specimens of each species from this locality.

sequently; but during the second sampling period 13 species with only 1 specimen each were discovered, adding significantly to the known diversity of the fauna.

It has been shown for several natural populations of living animals that the frequency distribution of species with different numbers of individuals in a population closely approximates a logarithmic series (WILLIAMS, 1964). One measure of the diversity of such a population is the index "α", which may range from 0 where all the specimens belong to a single species, to a very large number, its size dependent on the number of species obtained, where each specimen belongs to a different species (*op. cit.*, p. 148). This diversity index can be obtained by: $\alpha = n_1/x$, where "n_1" is the number of species represented by a single specimen and "x" is a variable dependent on the size of the sample, specifically on the ratio of the total number of individuals, to the number of groups (taxa), or in other words, the mean number of individuals per taxon. Using this index of diversity for our two sampling periods and for our total sample, the index "α" is: sample 1, 6.1; sample 2, 17.7; and for the total sample, 16.3. This index then reflects the considerably greater faunal diversity obtained during the second, as opposed to the first, sampling period.

Assuming that our crinoid sample comes from a population with a frequency distribution of

numbers of specimens per species that approximates a logarithmic series, it is possible to predict the effect of doubling the sample size on the total number of species obtained. Under this assumption, if we were able to collect an additional 500 specimens, approximately doubling the size of the present sample, and using the total diversity index cited above, we should add 11 more taxa to those presently known. Perhaps it will be possible ultimately to obtain 500 more specimens and to check the accuracy of this prediction.

The frequency with which species initially described were obtained during the second sampling period ranged between wide limits (Fig. 1). For instance, we obtained initially three specimens each of *Moscovicrinus bipinnatus* and *Nevadacrinus geniculatus*. Yet, during the next two years we collected 10 more specimens of the latter species but none of the former. *Polusocrinus amplus* and *Stenopecrinus? xerophilus* are two other species that are either poorly represented in the subsequent collections, or not at all. On the other hand, species like *Moapacrinus inornatus* and *Elibatocrinus elongatus* were either absent or represented by a single specimen originally, and we have since collected 13 and 6 specimens respectively of these two species.

Several factors obviously affect the degree of success in finding crinoids at this locality. Most important are the experience of the people aiding in the collecting, the weather conditions during the collecting period, and whether infrequent rainstorms in this part of the desert have uncovered new material not previously visible. We estimate that a total of approximately 68 man-hours were expended during the initial sampling period in order to obtain 236 specimens, or an average of about 3½ identifiable specimens recovered per man-hour. During the second collecting interval 299 specimens were obtained in 84 man-hours, or again about 3½ specimens per man-hour. These figures seem to indicate that additional collecting over a considerable period of time should continue to yield identifiable specimens and that the locality is far from exhausted.

LOCALITY

Considerable effort was spent attempting to find lateral extensions of the small crinoid-bearing lense from which almost all specimens were collected. Although we have been able to identify the same stratigraphic interval from which the crinoids came at several other places in the Arrow Canyon range, the Meadow Valley range to the north, and in the Las Vegas range to the west, crinoid-bearing limestone is not developed at any of these other areas. A second crinoid-yielding limestone has been found at the type locality in Battleship Wash, approximately 100 feet stratigraphically below the originally discovered fossiliferous layer. This bed is a medium gray, coarse-grained biomicrite 4 feet thick, containing scattered dark brown, iron-coated chert nodules, and has yielded all the silicified specimens of *Platycrinites* sp. described here, as well as many loose ossicles of several unidentified inadunates. The two crinoidal layers are separated by resistant, thick-bedded, gray coral- and fusuline-bearing biomicrite above, which grades down into pinkish-tan weathering silty and sandy fine-grained biomicrite. The lower crinoid horizon has yielded specimens from fault blocks up to one-half mile west of the original locality, and the upper bed has been traced this far as well, but it is only 1 or 2 feet thick and contains only loose ossicles at this distance. Both layers thin in all directions from approximately the center of the original collecting area (Lane & Webster, 1966, fig. 2), and are interpreted as biohermal accumulations of crinoid debris and other fossils.

ACKNOWLEDGMENTS

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SYSTEMATIC PALEONTOLOGY

Crinoid terminology and abbreviations follow those used by LANE & WEBSTER (1966). All specimen numbers for types are those of the University of California at Los Angeles, Invertebrate Paleontology catalogue, and all types are deposited in UCLA collections. Negatives of specimen photographs are on file in the Department of Geology, University of California at Los Angeles. Magnifications are approximate and all specimens are illustrated natural size except as indicated otherwise.

Subclass CAMERATA Wachsmuth & Springer, 1885

Order MONOBATHRIDA Moore & Laudon, 1943

Family PLATYCRINITIDAE Bassler, 1938

The occurrence of stem and thecal ossicles of a camerate crinoid in Lower Permian rocks is unusual and rare. Although characteristic elliptical columnals of platycrinitids have been reported several times from Pennsylvanian and Permian rocks in the United States, Russia, and China, the thecae of post-Mississippian platycrinitids are known only from the Permian of Timor.

The platycrinitid ossicles described below were all obtained from a limestone 100 feet stratigraphically below the bed that yielded all other crinoids described in this paper. Because the locality is the same and Permian camerate crinoids are of unusual interest, the platycrinitid ossicles are included in this report. All specimens are silicified and were released with acid. No dorsal cup with plates articulated was found, but in several instances a basal circlet and several radial plates that can be placed together were etched from the same small block, and clearly represent a single individual. Large, highly elliptical columnals are most plentiful and drew original attention to the bed, subsequently a number of basal circlets, radials, tegmen plates, and questionable brachials were obtained. Many of the ossicles are relatively large and the platycrinitid must have rivaled the largest known specimens in this family.

Genus PLATYCRINITES Miller, 1821

Type species.—Platycrinites laevis MILLER, 1821.

PLATYCRINITES sp.

Plate 1, figures 1-10

Columnals.—Individual columnals from regularly to highly elongate, elliptical in dorsal or ventral view. Ossicles attain lengths of 40 mm., heights of 10 mm., and proportions of length to width ranging from 40 mm. long and 14 mm. wide to 13 mm. long and 9 mm. wide. The articular surfaces are deeply concave, with a high straight-sided transverse ridge separating the two ligamentary fossae. The transverse ridge is flat-topped, has two rows of small denticles along its upper surface, and the ridge does not extend completely across the articular face, but terminates abruptly on either side of a narrow, cylindrical tube that rises from the bottom of the fossa and encloses the lumen. The transverse ridges on opposite sides of most columnals are parallel to each other so that series of at least six columnals are stacked on each other without any twist in the relative position of the ossicles, and a regularly corkscrew-twisted column typical of many platycrinitids is not developed. Each series of columnals that is not twisted is separated from adjacent such columnals by a single subquadrangular columnal that has upper and lower articular surfaces set at an angle of about 60° to each other, so that series of columnals above and below are offset at the same angle. The corners of offsetting columnals are bluntly rounded, project beyond edges of adjacent columnals and these ossicles are typically somewhat higher than adjacent ones. The edges of elliptical columnals may be planar or slightly concave but typically have an inconspicuous ridge at mid-height extending around the outer surface. Cirri or cirral scars are common on the narrowly rounded ends of elliptical columnals but do not occur on the wider and higher subquadrangular columnals, consequently the terms nodals and internodals do not seem appropriate for these two kinds of ossicles.

Basal circlets.—Four low, flat basal circlets have been found, but silicification has largely obliterated the sutures. Three of the circlets are

pentagonal in outline, but the fourth is quadrangular and may have supported only four radial plates. The hole in the center for communication between the cup interior and the stem axial canal is large and round. The outer surface of the circlet is smooth, except for the finely striate articular surface apposed to the proximal columnal. On the largest circlet the articular surface is elliptical but on other circlets it is subrounded. The largest circlet is 43 mm. in maximum diameter and each side is 26 mm. long. When in position on the cup the circlets would have had a height of about 5 mm.

Radials.—Fifteen isolated smooth, gently convex radial plates have been found, each having a wide straight lower edge and lateral edges that gently converge in a proximal direction. The upper corners of the radials have an oblique suture for contact with the lower edge of an interradial tegminal plate, and the distal border of each radial is concave distally. The radial facet is relatively wide and narrow, concave, inclined gently outward, and is about one-half of the radial in width. On well-preserved radials a narrow raised rim runs around the outer edge of a finely striate facet. Two radials show clearly that the facet was scalloped, with two narrow ridges separating the central part of the facet from each lateral side. The central part of the facet was surely occupied by a narrow axillary first primibrach that was less than one-half as wide as the facet. The lateral sides of the facet probably supported first secundibrachs. Other facets are not well enough preserved to determine details of their configuration.

Tegmen plates.—Six plates found in association with cup plates are judged to be interradial tegmen plates that were supported on the upper corners of subjacent radials. In addition, several flat, smooth polygonal plates are inferred to be plates from the central part of a platycrinitid tegmen. The larger interradial plates are widest proximally and have two equal sutural edges set at a large angle to each other, along which the radials were situated. The plates gradually taper distally, are smooth, and gently convex longitudinally, except for a low broad central node near the distal end. In addition to the two edges for contact with radials, six, seven, or eight other straight edges can be counted around the lateral and distal margins of each plate. Lateral edges adjacent to the proximal border are longer than more distal edges and probably represent sutural edges between adjacent plates of this type. None of the plates has a concave edge that might have bordered an anal opening.

Brachials.—Two or three small sets of biserial brachials have been recovered, but it is impossible to be certain that these belong to a platycrinitid, rather than a biserial inadunate, especially because individual ossicles of several small inadunates have also been released from matrix.

Remarks.—Permian genera of platycrinitids described from Timor by WANNER, such as *Plesiocrinus* and *Eutelecrinus*, differ from specimens described here either in having only five oral plates composing the tegmen, or in having the anal opening just above the two posterior radials. Study of isolated interradial tegmen plates from southern Nevada indicates that each of these plates has more sutural edges (up to nine) than would have been present if there were only five such plates in the tegmen. None of the 15 radial plates found,

EXPLANATION OF PLATE 1

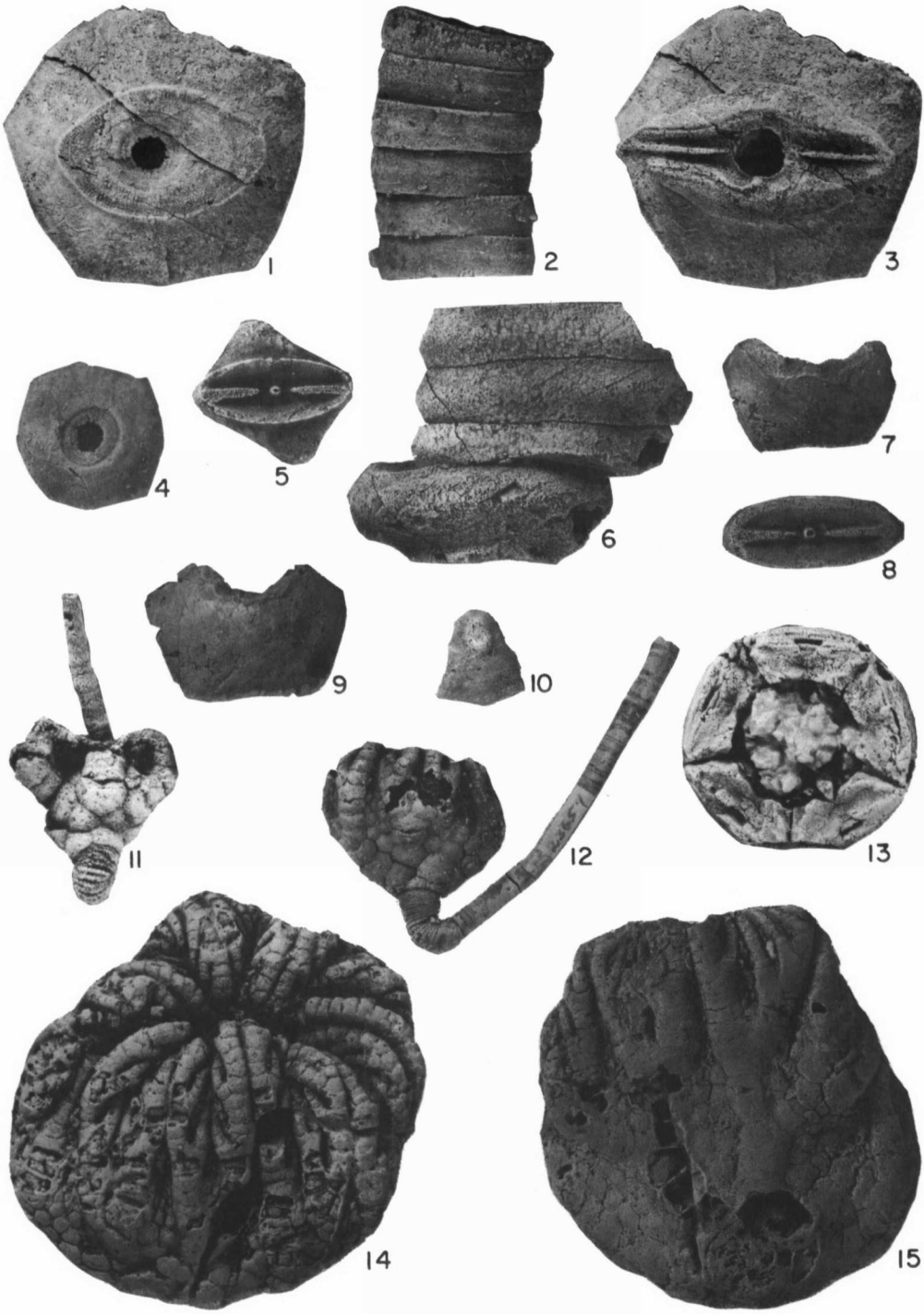
FIGURE

1-10. *Platacrinites* sp.——1. Hypotype (45813), view of dorsal surface of basal circlet showing columnal scar.——2. Hypotype (45810), side view of series of six columnals.——3. Hypotype (45814), with proximal columnal view similar to fig. 1.——4. Hypotype (45811), dorsal view of abnormal basal circlet.——5. Hypotype (45815), view of articular surface of "twist" columnal.——6. Hypotype (45809), side view of series of columnals with slightly offset "twist" columnal at base.——7. Hypotype (45812), view of radial associated with basal circlet of fig. 4.——8. Hypotype (45816), view of articular surface of normal columnal.——9. Hypotype (45817), lateral view of radial showing articular surface for brachials.——10. Hypotype (45808), dorsal view of tegmen plate (p. 7).

11-12. *Trampidocrinus phiala* LANE & WEBSTER.——11. Hypotype (45819), *E*-ray view of immature individual (*D* ray on right), ×2.——12. Paratype (23657), *D*-ray view, (*C* ray on right) (p. 10).

13. *Erisocrinus longwelli* LANE & WEBSTER. Hypotype (45850), oral view of radial circlet (p. 23).

14-15. *Trampidocrinus bellicus* LANE & WEBSTER. Hypotype (45820), oblique oral view showing endotomous branching and *D*-ray view (*B* ray on right) showing proximal bi-endotomous divisions (p. 10).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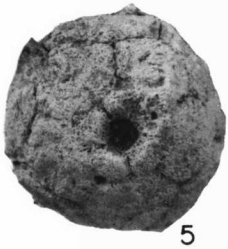
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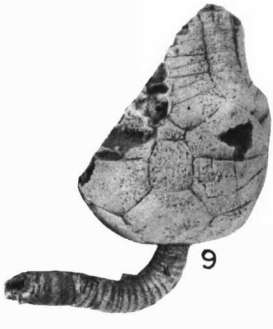
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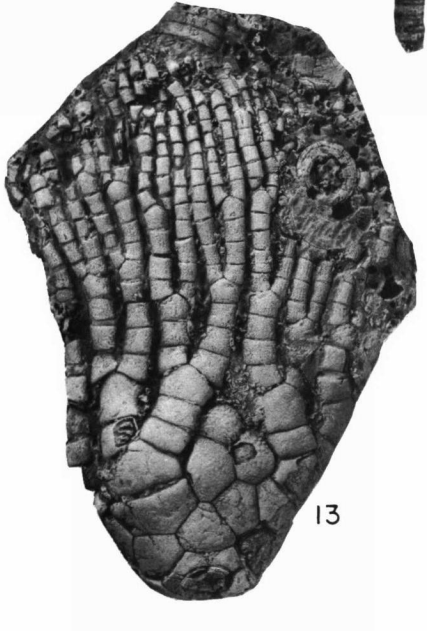
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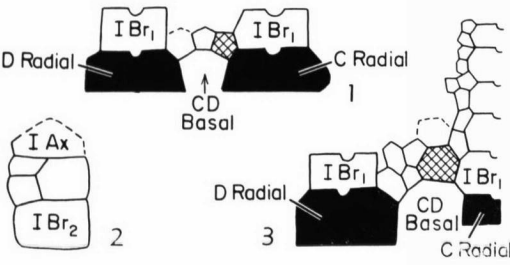


FIG. 2. *Nevadacrinus geniculatus* LANE & WEBSTER.——*1*. Posterior aspect of immature hypotype (45818).——2. Brachials showing arm injury, hypotype (45818).——3. Posterior aspect of paratype (23659). [Explanation: radials black, radianal cross-hatched.]

and none of the tegminal plates, shows evidence of a rounded sutural edge that could have bordered an anal opening low on the side of the tegmen. Consequently we judge that our specimens do not represent any of the specialized platycrinitid genera from Timor. The closest comparison with a complete theca that we can make is with *Platycrinites wachsmuthi* (WANNER), which has numerous tegminal plates, and an anal opening well up on the tegmen surface, and consequently we assign all the loose ossicles described here to *Platycrinites* sp.

Our specimens seem to differ from all of the Timor platycrinitids in having a much lower basal circlet, and a wider, narrower radial facet. Evidence that our specimens had first axillary primibrachs considerably narrower than the radial facet, so that first secundibrachs were in contact with the radial, is in accord with several Timor platycrinitid species and unlike virtually all Mississippian species of *Platycrinites*.

The peculiar arrangement of stem ossicles, with abrupt steplike twisting of the column is unlike any Mississippian platycrinitid, but is comparable to Middle Carboniferous platycrinitid stem ossicles from Russia (ARENDT & GEKKER, 1964, pl. 15, fig. 8).

Material.—Illustrated specimens are hypotypes nos. 45808-45817.

Subclass FLEXIBILIA Zittel, 1879

Order TAXOCRINIDA Springer, 1913

Family TAXOCRINIDAE Angelin, 1878

Genus NEVADACRINUS Lane & Webster, 1966

Type species.—*Nevadacrinus geniculatus* LANE & WEBSTER, 1966.

NEVADACRINUS GENICULATUS Lane & Webster, 1966

Figure 2

Nevadacrinus geniculatus LANE & WEBSTER, 1966, p. 16, pl. 1, fig. 2, 4, 7; fig. 3-5.

In addition to three specimens available for initial description of this species, two partial crowns and two arm fragments have been found subsequently. One of the new crowns is small, immature, and differs from larger specimens in having a single interradial plate in each of the four regular interrays, and in having a relatively smaller radianal. Three small plates of approximately equal size join the distal edge of the posterior basal (Fig. 2,*1*). One of the paratypes (no. 23659) has a series of small plates preserved along the right side of the posterior interray and in sutural contact with the first four primibrachials (Fig. 2,*2*). These plates presumably bordered the left side of the anal tube, which is not preserved but probably was inclined toward the right side of

EXPLANATION OF PLATE 2

FIGURE

1-2, 5-7, 9-10. *Moapacrinus inornatus* WEBSTER & LANE, n. sp.——1. Paratype (45832), view of crown showing general shape.——2. Paratype (45834), *A*-ray view, (*E* ray on right).——5-7. Paratype (45833), basal (*A* ray at top), *A*-ray view (*E* ray on right), and *CD*-interray view of dorsal cup, ×2.——9-10. Holotype (45831), *CD*-interray and basal (*B* ray at top) views (p. 18).

3-4, 8. Genus and species unknown, Species D.——3-4. Hypotype (45866), lateral and oral views of radial, ×2.——8. Hypotype (45867), oral view of brachial, ×2 (p. 31).

11. Genus and species unknown. Species E. Hypotype (45868), lateral view of root holdfast, cirri directed downward (p. 31).

12. *Stuartwellercrinus corbatoi* LANE & WEBSTER. Hypotype (45842), view of partial crown showing proximal part of column, ×2 (p. 20).

13-14. *Synyphocrinus permicus* LANE & WEBSTER.——13. Hypotype (45824), *CD*-interray view (*C* ray on right).——14. Hypotype (45825), *C*-ray view (p. 15).

the interray as in other taxocrinids. A specimen of *Taxocrinus ungula* illustrated by SPRINGER (1920, pl. 55, fig. 7) has a comparable posterior interray.

The new specimens also provide additional information about distal parts of the arms and variation in arm branching. All specimens show the fourth primibrach axillary, except one ray with five primibrachs mentioned in the first report. The secundaxil or tertaxil may be the second or fifth secundibrach or tertibrach, respectively. All observed arm branching is isotomous.

The immature specimen has been injured just above the second primibrach in the *E* ray. A full-sized primibrach occurs next above the second primibrach on the right side of the arm, but extends only halfway across the arm, and is bordered laterally by two small plates, one above the other, which fill the space on the left side of the arm up to a normal, axillary, fourth primibrach (Fig. 2,*3*). The patelloid process is absent on all abnormal brachials.

The immature specimen is a hypotype, no. 45818.

Order SAGENOCRINIDA Springer, 1913

Family SAGENOCRINITIDAE Bassler, 1938

Genus TRAMPIDOCRINUS Lane & Webster, 1966

Type species.—*Trampidocrinus phiala* LANE & WEBSTER, 1966.

TRAMPIDOCRINUS PHIALA Lane & Webster, 1966

Plate 1, figures 11-12

Trampidocrinus phiala LANE & WEBSTER, 1966, p. 20, pl. 2, fig. 1-2, 4; fig. 6.

In addition to the eight specimens available for the first study of this fauna, 21 crowns and 2 arm fragments of *Trampidocrinus phiala* have been found subsequently. These show that the arms branch up through quartibrachs, and rarely one additional division occurs in some rays. There are typically seven ranges of interbrachials above the primaxils, four or five ranges above the secundaxils, and two or three ranges above the tertaxils. Interbrachials have not been observed above higher axillaries.

The most interesting new specimen is a small, evidently immature specimen that has a dorsal cup only 7 mm. in maximum diameter. This specimen has two primibrachs and three secundibrachs, like mature specimens of *Trampidocrinus phiala*, but differs from larger individuals in several respects. The stem has the typical wedge-shaped columnal at the distal end of narrow columnals just below the cup, and the distal part of the stem is set at an acute angle to the proximal part. Only 12 columnals are present between the cup and the wedge-shaped columnal, however, whereas moderate-sized specimens have 18 or 20 columnals in this position, and large specimens have 25 to 40 such columnals. In addition, the *B* and *C* radials of the specimen are in contact with infrabasals. These features indicate that the peculiar stem and unusual cup configuration of *T. phiala* developed quite early in its ontogeny and was not a secondary development during the mature stage. The wedge-shaped columnal on either side of which the stem undergoes a sharp bend, must have developed prior to many of the thin columnals between the wedge-shaped columnal and the cup. More distal columnals surely were added to the distal side of the wedge-shaped columnal, at some distance from the base of the cup. The infrabasals of the immature specimen are large plates in relation to size of the basals and radials, and they project upward from the top of the column. In mature specimens of this species all but tips of the infrabasals are hidden under the proximal columnal, indicating that the infrabasals are concealed gradually during growth of the individual. Finally, the posterior basal supports a single anal plate, or radianal, directly above it, instead of the two plates present in all mature specimens. If the single plate is the radianal, then an additional plate is added above the left side of the posterior basal during growth.

Distal brachs of several new specimens show articular surfaces like those of *Forbesiocrinus nobilis* illustrated by SPRINGER (1920, pl. 24, fig. 24).

The immature specimen is a hypotype, no. 45819.

TRAMPIDOCRINUS BELLICUS Lane & Webster, 1966

Plate 1, figures 14-15; Figure 3

Trampidocrinus bellicus LANE & WEBSTER, 1966, p. 21-22, pl. 2, fig. 3, 5-7; pl. 3, fig. 1.

Currently 16 crowns and 6 arm fragments of this species are available for study. The specimens show variation in ornament of distal brachials, some of which have a small, sharp spine on the center of the plate, just below the patelloid process

notch. Some specimens have all higher brachials spinose, others have only a few such ossicles, whereas other specimens have all smooth brachials. The spines are developed only above the tertaxils and are most pronounced near the distal arm tips.

In the initial description of this species some question existed as to whether the arms were heterotomous. This uncertainty was due to poor preservation of the upper arms on available specimens, and the fact that one fragment of clearly heterotomous flexible arms could be assigned to *Trampidocrinus bellicus* only provisionally. Additional specimens reveal that *T. bellicus* does indeed have heterotomous arms, whereas *T. phiala* has isotomous arms, an important distinction between these two species. Consideration was given to the proposition that the quite different patterns of arm branching in the two species might be sufficient for generic separation. We now emphasize that the dorsal cups of the two species are identical and that fragmentary specimens which reveal only the proximal part of the crown cannot be assigned definitely to either species. Other genera of flexible crinoids, especially *Onychocrinus*, contain species with quite different modes of arm branching. Therefore we judge these two species, obviously related closely, to be best assigned to a single genus.

The arms of *Trampidocrinus bellicus* are bi-endotomous, using the term originated by Moore & Plummer (1940, p. 167). The first two divisions are isotomous, but above the tertaxils and all higher axillaries the inner branches remain undivided, resulting in simple unbranched arms toward the center of each half-ray (Fig. 3). The arms divide on the second primibrach and third secundibrach, like the arms of *T. phiala*. Tertibrach *4, 5,* or *6* is axillary and all higher divisions are on the third or fourth brachial of each series. Eighth-order brachs are the highest observed. The series of tertibrachs on the outer half of each secundaxil consistently have one more brach than the tertibrach series on the inner half of each secundaxil. This results in the quartaxils being situated at the same height above the base of the crown across each ray.

Other sagenocrinoids have bi-endotomous arms, which are especially well developed in such genera as *Dactylocrinus*, *Wachsmuthicrinus*, and *Synerocrinus*.

The illustrated crown is hypotype no. 45820.

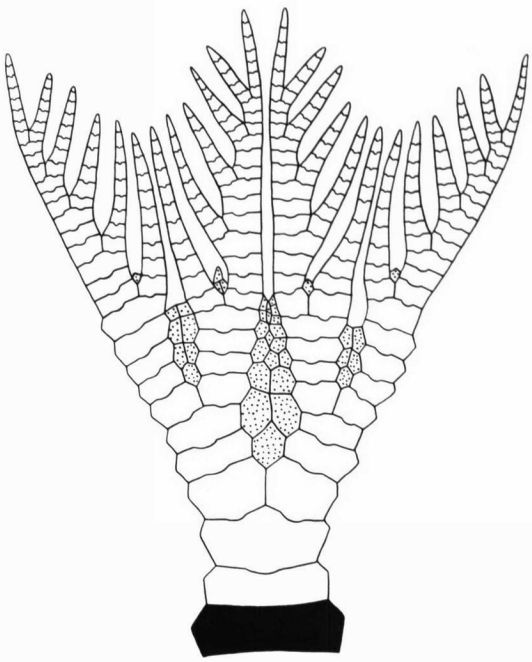


Fig. 3. *Trampidocrinus bellicus* Lane & Webster. Diagram of *D* ray of hypotype (45820), partly reconstructed in distal part. [Explanation: radial black, interbrachials stippled.]

Subclass INADUNATA Wachsmuth & Springer, 1885

Order DISPARIDA Moore & Laudon, 1943

Family ALLAGECRINIDAE Carpenter & Etheridge, 1881

Genus ISOALLAGECRINUS Strimple, 1966

Type species.—Allagecrinus bassleri Strimple, 1938.

ISOALLAGECRINUS EAGLEI Strimple, 1966

Plate 3, figures 9-10

Isoallagecrinus eaglei Strimple, 1966, p. 105, pl. 1, fig. 1-3.

This species was based on a single crown from the Red Eagle Limestone of middle Wolfcampian age (Early Permian) from Oklahoma. A slightly crushed crown from the Battleship Wash locality is closely similar to illustrations of the holotype, differing only in its slightly larger size and in having an apparently fused basal circlet. During preparation the cup was partly disarticulated and no trace of basal sutures could be seen internally. Fusion of basal plates is common in allagecrinids,

and until more specimens of the species are found we regard this as an intraspecific variation, or possibly a geographic variant, of *I. eaglei*. Measurements (in mm.) are: HC, 42; H, 5.0; W, 9.5; and H/W ratio, 0.53. The illustrated hypotype is no. 45821.

Order CLADIDA Moore & Laudon, 1943

Suborder POTERIOCRINITINA Jaekel, 1918

Family PELECOCRINIDAE Kirk, 1941

GENUS AND SPECIES UNKNOWN

SPECIES A

Figure 4,2

Poteriocrinites? sp. Lane & Webster, 1966, p. 23, pl. 3, fig. 2-4.

Three additional hypotypes of this species have been found which indicate that even tentative assignment to *Poteriocrinites* is erroneous. None of the new specimens is complete enough to serve as holotype of a species and we still lack knowledge of the posterior interray. The radial plates have two conspicuous ridges, rather than one, that begin just in front of the radial facet and extend obliquely down to the center of each radial-basal suture, becoming progressively higher proximally. The basals are large, highly tumid, stellate plates. Each of the distal basal edges has a short ridge at the center that adjoins one of the oblique radial ridges and merges into the highly convex center of the basal. Two other short proximal ridges extend obliquely out to the plate edges and probably would have met similar ridges on infrabasals if they were preserved. The proximal part of each basal rises almost vertically from the edge of the plate to the tumid plate center, and the infrabasal circlet would have been flat or concave, with only the distal tips of the infrabasals visible in side view. Two specimens have several large stellate anal sac plates preserved between the arms, and presumably a large porous sac was present in this species.

The pattern of ridges on radials and basals, and narrowness of the radial facet of this species are similar to features seen in *Stellarocrinus*, but the arms of the Nevada crinoids are quite different, branching on the fourth or fifth primibrach, rather than the first, and having uniserial rather than biserial brachials. The prominent comblike pinnules of the arms are reminiscent of those in some species of *Decadocrinus*, such as *D. tumidulus* (Miller & Gurley, 1894).

Species A resembles some species of *Pelecocrinus* in having a bowl-shaped cup, depressed cup plate angles, and rounded, uniserial arms which are widely separated, resulting in a loose, open aspect of the crown. None of the presently known pelecocrinid genera have arms that branch as high above the cup as in Species A, and the arms are not known for any of the genera in the closely related family Mollocrinidae Wanner, 1916. Nevertheless it is with this group of crinoids, rather than the Poteriocrinitidae, that we now believe this species to be related. It seems almost certain that the known hypotypes of Species A represent a new, as yet undescribed genus.

Three new hypotypes of Species A are nos. 45870-2.

Family STELLAROCRINIDAE Strimple, 1961

Genus STELLAROCRINUS Strimple, 1940

Type species.—Cyathocrinus stillativus White, 1879.

STELLAROCRINUS CUNEATUS Lane & Webster, 1966

Stellarocrinus cuneatus Lane & Webster, 1966, p. 24, pl. 3, fig. 5, 7; pl. 13, fig. 21; fig. 7.

EXPLANATION OF PLATE 3

Figure

1-2. *Agnostocrinus typus* Webster & Lane, n. gen., n. sp. Holotype (45826), *A*-ray (*E* ray on right) and *CD*-interray view (*C* ray on right) (p. 16).

3. *Stellarocrinus comptus* Webster & Lane, n. sp. Holotype (45822), basal view, *A* ray directed upward (p. 13).

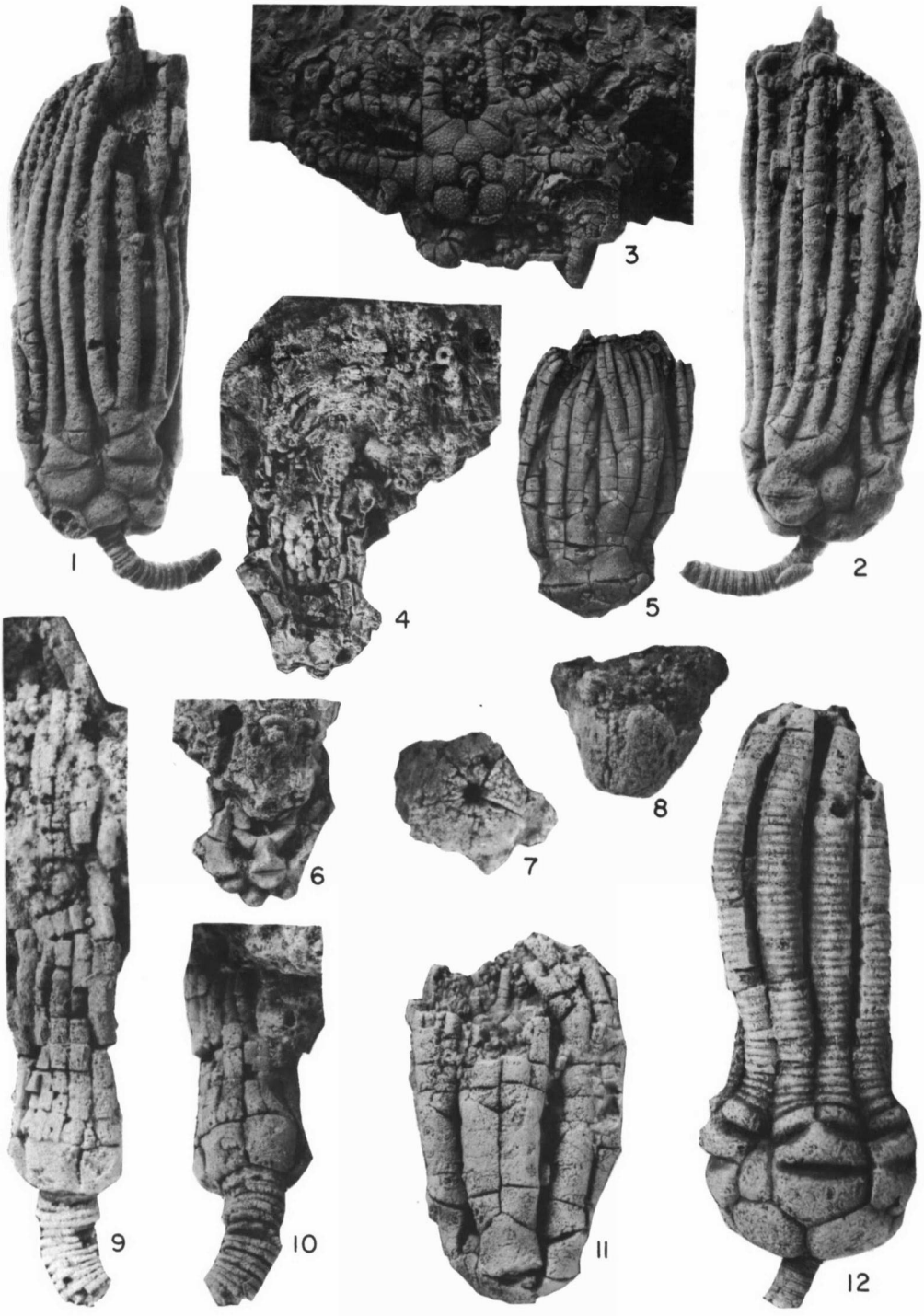
4, 6. *Stellarocrinus?* sp. Hypotype (45823), ventral view showing tegmen plates and dorsal view of incomplete crown (p. 13).

5, 11. *Exocrinus moorei* (Lane & Webster).——5. Hypotype (45841), *D*-ray view (primanal on right). ——11. Hypotype (45840), *C*-ray view (*B* ray on right) of immature specimen, ×2 (p. 19).

7-8. *Petschoracrinus?* sp. Hypotype (45844), basal and side views of infrabasal circlet, ×2 (p. 21).

9-10. *Isoallagecrinus eaglei* Strimple. Hypotype (45821), *CD*-interray view (*C* ray on right) and *A*-ray view (*E* ray on right), ×2 (p. 11).

12. *Moapacrinus rotundatus* Lane & Werster. Hypotype (45830), *C*-ray view, (*B* ray on right) of complete crown (p. 17).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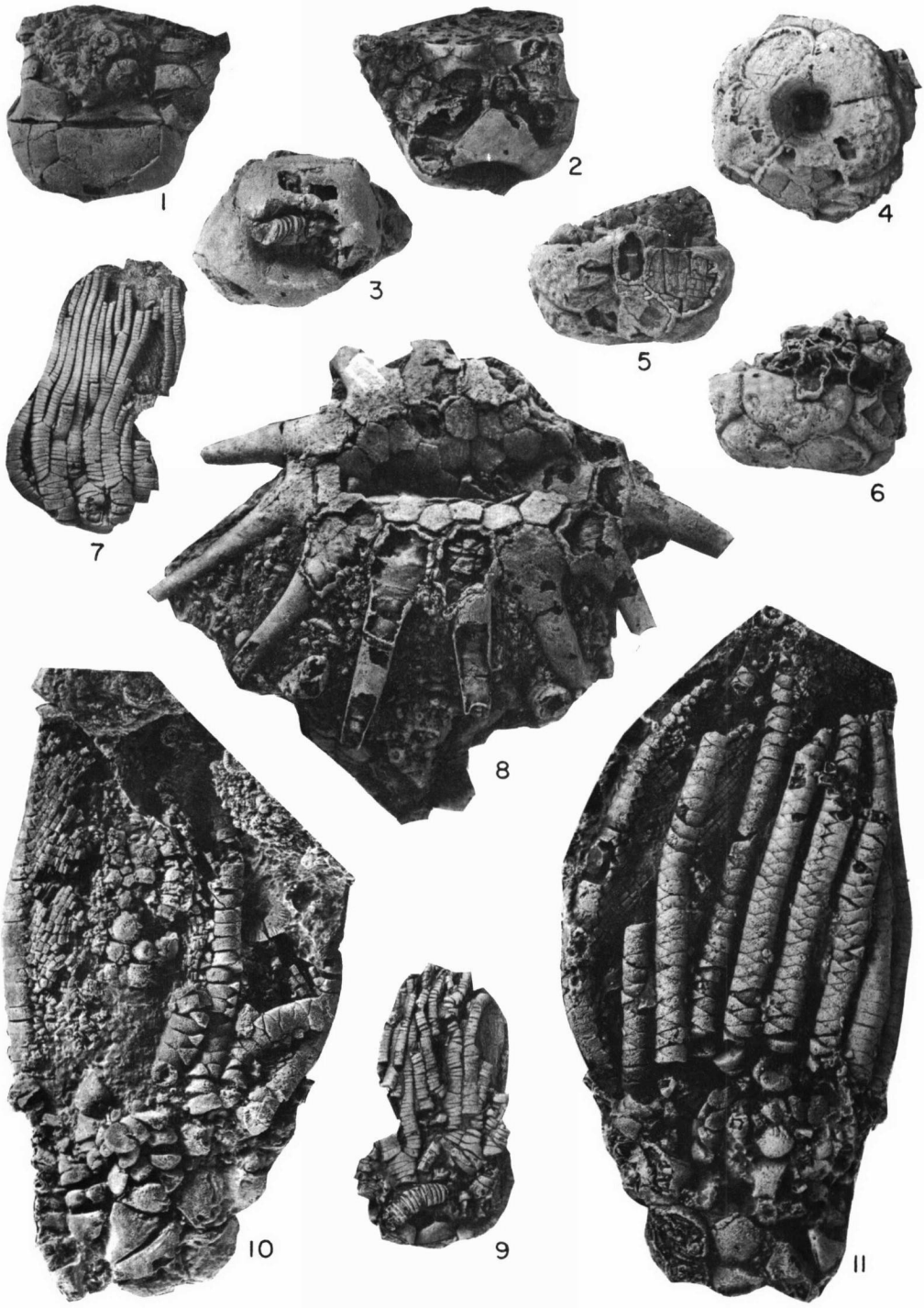
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Five reasonably complete crowns and three sets of arm fragments are available for study. One crown is badly weathered but has nearly 6 cm. of attached column, which is round, consisting of nodals and two different sizes of internodals, which require a series of four columnals before repetition of the same sequence. Nodals are smoothly convex on lateral edges, converging into a median ridge; no cirri or articular surfaces were observed. Larger internodals are two-thirds the height of nodals and smoothly rounded on lateral edges; a smaller internodal is one-third the height of a nodal, and has a nodose edge. All columnals have narrow denticulate rims where they join, and the axial canal is round. Measurements of a sequence of nodals and two internodals 1 cm. below the cup are (in mm.): nodal: H, 1.2; W, 5.3; larger internodal: H, 0.8; W, 4.4; smaller internodal: H, 0.4; W, 4.0.

The described hypotype is no. 6267.

STELLAROCRINUS COMPTUS Webster & Lane, new species

Plate 3, figure 3

Description.—Crown small, spreading, arms widely separated. Dorsal cup low bowl-shaped, all plates ornamented with conspicuous small nodes evenly scattered across plates. Infrabasal circlet small, pentagonal, flat, occupying bottom of small, narrow basal concavity. Basals strongly arched longitudinally, pentagonal, posterior basal truncate above for contact with single anal plate in cup. Radials wider than high, lower edges along basal-radial sutures distinctly concave. Outer surface of each radial extends inward along upper corners of each plate, bounding radial facets, which are distinctly narrower than radial plates. Primibrachs axillary in all rays, higher than wide, with slightly concave lateral margins, nodose, with nodes closely spaced and aligned along median axis of each plate. All higher brachials nodose, cuneiform, strongly rounded; sixth secundibrachs are narrowly triangular axillary plates, no higher branching observed. Stem pentagonal.

Remarks.—*Stellarocrinus comptus*, n. sp., differs from *S. cuneatus* Lane & Webster, from the same locality, in having nodose rather than ridged ornament, relatively higher axillary plates and in lacking spines on brachials. Other described species of the genus are more closely similar to *S. cuneatus* than to *S. comptus*, especially in having all or part of the brachs arranged in biserial manner. The difference between the strongly cuneate uniserial brachs of the new species and the similarly shaped biserial ones of other species of *Stellarocrinus* is judged not to be of generic significance.

Name.—The specific name *comptus* (Latin) means ornamented, and refers to the delicate nodes on the cup and arm plates.

Material.—The holotype and only known specimen is no. 45822.

Measurements.—Measurements of the holotype (in mm.) are: H, 5.1 (approx.); W, 14.5 (approx.); WIBB, 4.3 (approx.); HB, 4.4; WB, 4.5; HR, 4.1; WR, 7.2; $HIBrr_1$, 3.5; $WIBrr_1$, 5.0; $HIIBrr_1$, 2.3; $WIIBrr_1$, 3.3; $HIIAxx_1$, 2.1; $WIIAxx_1$, 3.2.

STELLAROCRINUS sp.

Plate 3, figures 4, 6

Description.—Crown small, cylindrical, dorsal cup low, basal part unknown. Basals small, pentagonal, each with prominent, high central node. Radials wider than high, with large, transversely elongate central nodes; radial facet not quite as wide as radial. First primibrach axillary, higher than wide, medially constricted, with prominent longitudinal keel extending almost to distal tip where it branches and continues onto secundibrachs; upper facets of primaxil set at low angle to each other, primaxil and first secundibrachs

EXPLANATION OF PLATE 4

FIGURE

1-3. *Graphiocrinus scopulus* Lane & Webster. Hypotype (45855), *A*-ray view (*E* ray on right), *CD*-interray view (*C* ray on right), and basal view (*A* ray on top) of partial crown (p. 26).

4-6. *Endelocrinus torus* Webster & Lane, n. sp. Holotype (45853), basal view (*A* ray on top), *CD*-interray view (*C* ray to right), and *B*-ray view (*R* ray to right) (p. 24).

7-9. *Texacrinus distortus* Webster & Lane, n. sp. Holotype (45837), side view showing exotomous arm branching and basal view of crushed crown (p. 19).

8. *Schedexocrinus* sp. Hypotype 23682), oral view of tegmen cap, ×0.7 (p. 30).

10-11. Genus and species unknown, Species C. Hypotype (45847), *D*-ray view (*C* ray on right) and *A*-ray view (*E* ray on right) of crushed crown (p. 22).

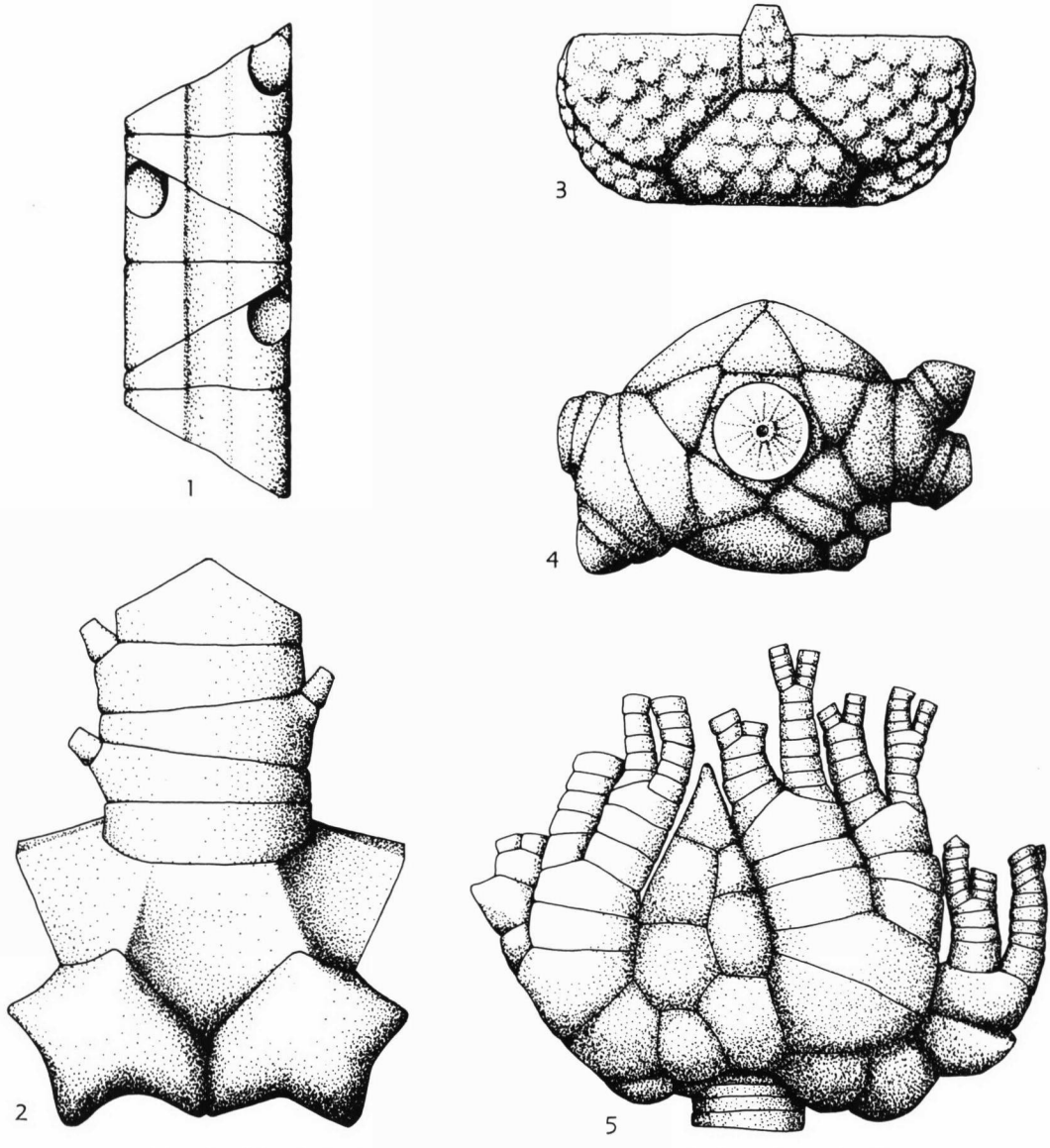


FIG. 4. Morphological features of southern Nevada Permian crinoids.

1. Reconstruction of dorsal aspect of arm fragment of Species B, showing syzygies, hypotype (45843), ×15.

2. Reconstruction of basals, radials and primibrachs of Species A, based on hypotypes (45872, 39671), ×4.

3. Endelocrinus torus WEBSTER & LANE, n. sp., dorsal cup of holotype (45853), ×1.7.

4-5. Neozeacrinus wanneri WEBSTER & LANE, n. sp., dorsal and posterior views of holotype (45858), ×1.5, ×2.

together forming Y-shaped outline; succeeding brachs are high, narrow, and additional branching cannot be observed. Anal sac narrow, elongate, composed of three or more alternating rows of narrow, high, hexagonal, half-barrel-shaped plates. Other parts of crown and column not preserved.

Remarks.—The only genus we have been able to discover that has widely flaring first secundi-

brachs above each primaxil like this specimen is *Stellarocrinus*, which differs from our specimen in having a much lower primaxil and brachials that are strongly cuneate or biserial rather than high and slender. Because the posterior interray and base of the cup is not preserved, the Nevada specimen is not suitable to serve as holotype of a new species.

Material.—One weathered, incomplete crown is hypotype no. 45823.

Measurements.—Measurements of hypotype are (in mm.): HC, 49.5 (approx.); HB, 3.7; WB, 4.3; HR, 4.1; WR, 6.0; HIBrr$_1$, 5.5; WIBrr$_1$, 5.0; HIIBrr$_1$, 5.0; WIIBrr$_1$, 3.3.

Genus CELONOCRINUS Lane & Webster, 1966

Type species.—*Celonocrinus expansus* LANE & WEBSTER, 1966.

CELONOCRINUS EXPANSUS Lane & Webster, 1966

Celonocrinus expansus LANE & WEBSTER, 1966, p. 48, pl. 11, fig. 1-2, 4-5; fig. 18.

Five additional arm fragments of this species do not yield any new information. Further preparation of the holotype of the species indicates that pinnules are present, at least in the middle parts of the arms. Several pinnule facets and fragments of two pinnules can be seen. Pinnular facets could not be observed on either distal or proximal brachials.

We are transferring this genus from the Erisocrinidae to the Stellarocrinidae because of its close resemblance to *Brychiocrinus* MOORE & PLUMMER, 1940, which we believe is a valid genus and not a synonym of *Stellarocrinus*. *Brychiocrinus* differs from *Stellarocrinus* in having smooth cup plates, differently shaped radial plates that have less conspicuous radial notches, and in having biserial arms that have departed farther from a cuneate condition than in *Stellarocrinus*. *Celonocrinus* has a dorsal cup that closely resembles that of *Brychiocrinus*, especially in configuration of the radial plates, which are wide, short, have slightly concave proximal edges, and short interradial sutures. The small triangular axillaries of the biserial arms also ally *Celonocrinus* to other stellarocrinids, although it differs from these genera in having much wider, flatter arms and exotomous branching.

Family BLOTHROCRINIDAE Moore & Laudon, 1943

Genus SYNYPHOCRINUS Trautschold, 1881

Type species.—*Synyphocrinus cornutus* TRAUTSCHOLD, 1881.

SYNYPHOCRINUS PERMICUS Lane & Webster, 1966

Plate 2, figures 13-14

Synyphocrinus permicus LANE & WEBSTER, 1966, p. 27, pl. 4, fig. 1-7, fig. 8.

Discovery of a fairly complete and several fragmentary crowns or sets of arms, along with original specimens on which *Synyphocrinus permicus* was based, results in a total of 13 known specimens of this species. The new material adds significantly to several details of morphological knowledge of the species. Small nodes may be present on the anal plates and a faint longitudinally aligned shagreen can be seen on some brachs. Both of these ornamentations are either variable in occurrence or they may be lost on some individuals by silicification; all specimens are silicified, but all do not show ornamentation.

Arm divisions include two proximal isotomous branches followed by six bi-endotomous divisions. Axillary brachs are first primibrach, secundibrach 2 or 3, third or fourth tertibrach, quartibrach 4 or 5, fourth to seventh VBr, and third or fourth VIBr, VIIBr, and VIIIBr. Thus if all rays have a similar branching pattern, a maximum of 14 arms for each half-ray, or a total of 140 arms for an individual, would result.

The species name *permicus* was assigned because we believed this was the first nominal species of *Synyphocrinus* of Permian age. WANNER (1924) described *S. trautscholdi* and reallocated *Graphiocrinus? indicus* WANNER, 1916, to *Synyphocrinus*, and in 1937 described *S. weidneri*, all from the Timor Permian. The above species described by WANNER possess a single anal plate in the cup and clearly are not *Synyphocrinus* as redefined by YAKOVLEV & IVANOVA (1956).

Illustrated hypotypes are nos. 45824 and 45825.

Genus AGNOSTOCRINUS Webster & Lane, n.gen.

Type species.—*Agnostocrinus typus* WEBSTER & LANE, n. sp., here designated.

Diagnosis.—Cup bowl-shaped, with basal concavity; one anal plate; arms uniserial, branching

on first primibrach in all rays and on first secundibrach in *A*, *C*, and *D* rays only; anal tube long, cylindrical, narrow.

Remarks.—This new genus is based on a single, well-preserved complete crown with an unusual combination of diagnostic characters that results in uncertainty concerning proper familial allocation of the new genus and its probable ancestral type. The arms of *Agnostocrinus* are virtually indistinguishable from those of *Ulrichicrinus* SPRINGER (1926), a genus of the Blothrocrinidae confined to Mississippian and Lower Pennsylvanian rocks. The arms of *Ulrichicrinus* are long, slender, rounded, and have cuneiform brachs, like *Agnostocrinus*, and typically branch on first primibrach and secundibrach in the *A*, *C* and *D* rays. Other poteriocrinoids that have two arm branches in most proximal position typically either have fewer arms in the *A* ray than in the *B* or *E* rays *(Arroyocrinus)*, or have biserial arms *(Ethelocrinus)*. However, *Ulrichicrinus* has a high, cone-shaped cup with infrabasals visible in side view and has three anal plates. The dorsal cup of *Agnostocrinus* is comparable to that of crinoids usually assigned to the family Erisocrinidae, but none of the erisocrinids has arms comparable to those of the new genus.

Consequently one could postulate that *Agnostocrinus* evolved from a blothrocrinid like *Ulrichicrinus* by retaining a similar pattern of arm branching, and that the cup evolved by development of a basal concavity and elimination of two anal plates from the cup. Alternatively, one could argue that *Agnostocrinus* is an erisocrinid that evolved from a genus like *Graphiocrinus* by development of additional arm branches just above the primaxils in three rays. This uncertainty concerning the phylogeny of *Agnostocrinus* probably can only be resolved by discovery of additional related specimens in Upper Pennsylvanian or Lower Permian rocks.

Name.—The generic name is from the Greek *agnostos*, meaning unknown, and *krinon*, meaning lily.

AGNOSTOCRINUS TYPUS Webster & Lane, n.sp.
Plate 3, figures 1-2

Disarticulated ossicles, LANE & WEBSTER, 1966, p. 57, pl. 13, fig. 9-10.

Description.—Crown cylindrical. Dorsal cup low, bowl-shaped, with basal concavity. Infrabasals not preserved. Basals tumid, pentagonal, strongly curved proximally forming outer edges of basal concavity; posterior basal truncate above along suture with anal. Radials wider than high, central part produced as large, transverse node. Narrow lip on lateral edges of distal surface forms wide shallow slot for proximal end of primibrach, lip widest on posterior side of *C* and *D* radials. Radial facets not full width of radials, narrow radial notch. Anal *X* large, convex, lower one half in cup, pentagonal in outline, supporting two smaller anals above. First primibrachs axillary in all rays, wider than high, transversely convex. First secundibrachs axillary in *A*, *C*, and *D* rays, large, transversely convex, and medially constricted; *B* and *E* ray primaxils supporting two unbranched arms. Arms rounded, brachs slightly cuneate proximally, becoming strongly wedge-shaped distally. Pinnules long, slender, directed obliquely upward. Anal tube long, slender, cylindrical, projecting above distal tips of arms. Composed of six rows of hexagonal plates that have two pores on each side. Distal tip of sac not preserved. Column round, axial canal round, sides of nodals rounded, three to seven internodals between nodals; cirri not observed.

Name.—The species name is Latin *typus*, meaning type or example.

Material.—The holotype, a crown, no. 45826 and two disarticulated ossicles, hypotypes nos. 39676 and 39677.

Measurements.—Measurements of the crown in mm. are: HC 74.5; H 8.2; W_{max} 20.8; W_{min} 14.0; W_{aver} 17.4; HB 6.0; WB 7.8; HR 5.5; WR 10.1; $HIBrr_1$ 7.0; $WIBrr_1$ 8.9; $HIIBrr_1$ 5.3; $WIIBrr_1$ 6.4; $HIIIBrr_1$ 3.0; $WIIIBrr_1$ 4.4; $HIIIBrr_2$ 2.5; $WIIIBrr_2$ 3.7.

Genus ELIBATOCRINUS Moore, 1940

Type species.—Elibatocrinus leptocalyx MOORE, 1950.

ELIBATOCRINUS ELONGATUS Webster & Lane, n.sp.
Plate 5, figures 1-2

Elibatocrinus sp. LANE & WEBSTER, 1966, p. 30, pl. 10, fig. 7.

Description.—Crown elongate, narrow; dorsal cup truncate cone-shaped, slightly higher than wide, plates smooth. Three steeply upflaring infrabasals, with small one in *C* radius, higher than wide, form considerable part of cup side; circlet

has narrow, truncate base for reception of proximal columnal. Five large basals, higher than wide, with long interbasal sutures, hexagonal except for *CD* basal which is heptagonal. Five pentagonal radials, wider than high, longitudinally straight along mid-line but slightly concave along lateral edges; radial facet occupies nearly full width of radial. Three large anal plates in cup; radianal bordered by right tube plate, *C* radial, *BC* and *CD* basals, and anal *X*. A large tube plate is above and between anal *X* and right tube plate.

Primibrachs axillary in all rays, medially restricted, wider than high, smooth or covered with small nodes. Secundibrachs strongly cuneate, but not biserial, high proximally, becoming lower and triangular in outline distally, strongly rounded externally, smooth or finely nodose proximally, each with one slender pinnule on high side. Tertibrachs present in some specimens with secundibrach *3* or *5* axillary. Anal tube narrow, elongate, extending at least one-half height of arms; composed of six or more alternating columns of small stellate plates, each with four to eight deeply incised lateral slits. Stem round, columnals thin, becoming slightly higher distally, edges sharply denticulate, nodals and internodals not distinguishable.

Remarks.—Elibatocrinus elongatus is the first species of the genus described from Permian rocks and the only one besides *E. hoodi* STRIMPLE for which the arms are known, differing from the latter in its larger size, having rounded rather than keeled brachials, in possessing nodose ornament on some proximal brachials, and in having tertibrachs developed in some specimens. The holotype has ten arms, but three paratypes all have tertibrachs in at least some rays. Until more and better specimens are available we regard this to be intraspecific variation.

Elibatocrinus was assigned to the Blothrocrinidae by MOORE & LAUDON (1943) and to the Scytalocrinidae by STRIMPLE (1961). Assignment of this genus to the latter family is doubtful, because all scytalocrinids have only ten arms, and the new species described here has more than ten arms. Although no other blothrocrinids have just three infrabasals, we believe this family to be the most logical place for assignment of *Elibatocrinus* at the present.

TABLE 3.—*Measurements of* Elibatocrinus elongatus WEBSTER & LANE, *n. sp.*

	Holotype No. 45827	Paratype No. 39658
HC	150.0[a]	48.3[a]
H	20.0[a]	21.3[a]
W	17.0[a]	.....
HIB[b]	7.6	6.4[a]
WIB[b]	5.7	.....
HB	9.7	9.0
WB	7.0	.....
HR	6.0	5.3[a]
WR	9.2	8.2
HIBrr	5.5	6.2
WIBrr	7.8	7.4
$HIIBrr_1$	5.7	.....
$WIIBrr_1$	3.1	.....

All abbreviations for measurements are from MOORE & PLUMMER (1940).
[a] Approximate or incomplete.
[b] Small infrabasal.

Name.—The species name is from Latin *elongatus* meaning prolonged, and refers to the elongate nature of the crown.

Material.—The description is based on six specimens; one crown, the holotype no. 45827; three partial crowns, paratypes nos. 45828-9, 39658; and two arm fragments.

Measurements.—See Table 3.

Family CROMYOCRINIDAE Jaekel, 1918

Genus MOAPACRINUS Lane & Webster, 1966

Type species.—Moapacrinus rotundatus LANE & WEBSTER, 1966.

MOAPACRINUS ROTUNDATUS Lane & Webster, 1966

Plate 3, figure 12

Moapacrinus rotundatus LANE & WEBSTER, 1966, p. 31, pl. 6, fig. 1-10; fig. 9.

This species is the most abundant one in the Battleship Wash fauna, with 137 specimens, mainly arm fragments, known. Dorsal cup plates show variously developed ornament, ranging from some that have nearly smooth plates to others bearing coarse nodes and irregular wavy ridges. Even the nearly smooth cups show faint nodose ornament on the distal part of the radials. The differing development and coarseness of nodes is thought to be intraspecific variation, but may be related to the degree of individual silicification.

When *Moapacrinus* was originally described a complete crown was not available, although one

has been found subsequently. This specimen shows clearly a constriction of the arms at a short distance above the cup, a feature typical of many cromyocrinids, although also developed on other inadunates and some camerates. This constriction of the arms gives a characteristic aspect to a crinoid crown and is here designated as **arm girdle.** Brachials are laterally interlocked from the top of the cup to the base of the arm girdle, suggesting that most arm flexure in assuming a feeding position was done above the girdle. Interlocking of proximal brachs would have given more rigidity to the crown when the arms were in a closed position.

Two arm fragments show arms (three on one, and two on the other) which were apparently broken off distally and subsequently regenerated. The regenerated sections lack elongate nodes on the brachials and are more wedge-shaped than normal plates. Several specimens show a random brach which does not extend fully across the arm, resulting in a local biserial condition that affects only one or two brachs. It is not clear whether these represent injuries or are simply growth irregularities.

Several specimens of an undescribed species of *Moapacrinus* from Permian rocks of Kansas show close affinity to *M. rotundatus.*

MOAPACRINUS INORNATUS Webster & Lane, n.sp.
Plate 2, figures 1-2, 5-7, 9-10

Description.—Crown elongate, slender, subcylindrical, widest at primibrachs. Dorsal cup truncate bowl-shaped, twice as wide as high, slightly oval in outline when viewed from above or below with long axis through *B* ray-*DE* interray, base slightly convex, plates smooth, sutures faintly impressed to smooth. Infrabasals five, large, dart-shaped, slightly upflared distally, distal tips visible in side view, circlet pentalobate, slightly smaller than basal plate; stem impression round. Basals five, large, slightly wider than high to equidimensional, hexagonal except for posterior basal which is heptagonal, gently concave transversely and longitudinally, distal extremities nearly vertical. Five radials large, pentagonal, nearly twice as wide as high, gently convex longitudinally and transversely, facet full width of radials, radial-primibrach sutures impressed. Anal *X* large, hexagonal, two-thirds below cup summit, flat to faintly convex transversely, gently convex longitudinally, adjoined by *C* and *D* radials, *CD* basal, *C* and *D* primibrachs and tube plate. Arms ten, long, wide, preserved in close lateral contact. First primibrach axillary in all rays, nearly twice as wide as high, occupying full width of radials, distal tips protruded sharply, resulting in a pronounced node formed by the distal part of the primibrach and inner lateral ends of first secundibrachs. $IIBrr_1$ largest secundibrachs, nearly twice as wide as high, moderately convex longitudinally, slightly convex transversely. Succeeding secundibrachs wide, short, gently convex transversely, straight longitudinally, approximately three times as wide as high, slightly cuneate.

Column round, formed by alternating series of nodals and internodals; nodals five times higher than internodals, crenulate outer surface. Axial canal circular.

Remarks.—*Moapacrinus inornatus* differs from *M. rotundatus*, the only other described species, in having smooth cup plates, only faintly impressed to smooth sutures, brachials that lack transverse ornament, and in having distal tips of primibrachs and inner lateral ends of first secundibrachs, forming nodelike projection.

Name.—The species name is from the Latin *in* and *ornamentum*, meaning not and decoration, respectively, and refers to the lack of ornamentation of the plates.

Material.—The holotype, no. 45831, is an uncrushed dorsal cup with proximal parts of the arms attached; three crushed or incomplete crowns and two dorsal cups are paratypes nos. 45832 to 45836. Seven additional fragmentary specimens, mostly sets of arms, are known.

Measurements.—See Table 4.

Family TEXACRINIDAE Strimple, 1961

The four known Pennsylvanian poteriocrinoids characterized by exotomously branching arms were placed together in this family by Strimple (1961). The included genera are *Texacrinus* Moore & Plummer, 1940; *Haeretocrinus* Moore & Plummer, 1940; *Schistocrinus* Moore & Plummer, 1940, and *Marathonocrinus* Moore & Plummer, 1940. We have placed *Marathonocrinus* in the Timorechinidae, based on first knowledge of the dorsal cup in this gennus (Lane & Webster,

TABLE 4.—*Measurements of* Moapacrinus inornatus WEBSTER & LANE, *n. sp.*

Abbreviations	Holotype No. 45831	Paratype No. 45836	Paratype No. 45833	Paratype No. 45834	Paratype No. 45832	Paratype No. 45835
HC	.....	77.0*	55.0	50.0*	.....	.....
H	12.4	.....	.....	.....	7.5	6.9
W	25.0	.....	.....	.....	13.7	11.9
WS	4.7	.....	.....	.....	2.7	3.0
WIBB	10.0	.....	.....	.....	5.1	5.3
WIB	5.0	.....	.....	.....	2.6	2.7
HB	10.2	.....	8.2	4.0	5.2	5.0
WB	11.0	.....	8.2	4.0	5.2	5.4
HR	7.6	.....	5.3	5.9	4.5	4.0
WR	14.1	14.6	10.8	11.0	7.8	7.6
$HIBrr_1$	8.0	7.0	5.5	6.9	.....	.....
$WIBrr_1$	14.2	14.6	10.8	11.0	.....	.....
$HIIBrr_1$	3.4	4.1	3.8	3.8	.....	.....
$WIIBrr_1$	7.5	8.4	6.4	7.0	.....	.....
$HIIBrr_2$	1.8	2.0	2.2	2.5	.....	.....
$WIIBrr_2$	1.8	2.0	2.2	6.8	.....	.....
$HIIBrr_3$	1.8	1.7	2.0	1.9	.....	.....
$WIIBrr_3$	5.5	6.7	5.9	6.8	.....	.....

* Approximate.

1966), and have reservations about the other three genera forming a natural assemblage. Although the three remaining genera all have exotomously branching arms they have quite different dorsal cups, and it is possible that exotomous arms were independently, although rarely, developed in different lineages.

Genus TEXACRINUS Moore & Plummer, 1940

Type species.—Texacrinus gracilis MOORE & PLUMMER, 1940.

TEXACRINUS DISTORTUS Webster & Lane, n.sp.

Plate 4, figures 7, 9; Plate 7, figures 1, 5

Description.—Crown of moderate size, cylindrical. Dorsal cup low cone-shaped, plates smooth. Infrabasal circlet visible in side view. Basals gently convex transversely, pentagonal, with straight proximal edges. Radials gently convex transversely, wider than high; radial facets shallow, occupying full width of radials. Three anal plates in cup, radianal pentagonal, in contact with *BC* and *CD* basals, *C* and *D* radials, and supporting anal *X* and right tube plate above. Two higher anal plates are preserved above anal *X* and right tube plate. First primibrach axillary in all rays, supporting six cuneiform secundibrachs on each side; fifth secundibrach narrower than lower ones, and failing to extend completely across arm, so secundaxil and fourth secundibrach touch on one side of each arm. All arm branches to outside of each ray unbranched above secundaxils, and three higher branches occur toward mid-line of ray in each half ray, resulting in exotomous arms. Brachials are about three times wider than high, gently rounded, and adjacent branches are closely appressed; all axillaries low and broad. Brachial just below most, but not all, axillary plates is shorter than other plates, resulting in a local biserial condition just below most axillaries, such as was described for secundibrachs. Stem round; anal sac unknown.

Remarks.—Texacrinus distortus differs from the type species of the genus, *T. gracilis*, in having fewer brachs between axils, somewhat wider brachs, and peculiar brachs just below axils that do not extend completely across the arm. *T. coniformis* STRIMPLE has second branching on the third to fifth secundibrach, rather than the sixth, and lacks the single biserial plate below axillaries. Other species assigned to the genus by STRIMPLE (1952) have bowl-shaped cups and do not resemble closely the new species.

Name.—The Latin name *distortus* means misshapen or deformed, in reference to the crushed nature of the specimens.

Material.—The holotype is no. 45837; a partial crown, no. 45838, and a set of arm fragments, no. 45839, are paratypes.

Measurements.—See Table 5.

Family TIMORECHINIDAE Jaekel, 1918

Genus EXOCRINUS Strimple, 1949

Type species.—Exocrinus multirami STRIMPLE, 1949.

EXOCRINUS MOOREI (Lane & Webster), 1966

Plate 3, figures 5, 11

Marathonocrinus moorei LANE & WEBSTER, 1966, p. 34, 35; pl. 7, fig. 1-2, 5; fig. 10.

Examination of the holotype of *Marathono-*

TABLE 5.—*Measurements of* Texacrinus distortus WEBSTER & LANE, *n. sp.*

Abbreviations	Holotype no. 45837	Paratype no. 45838
WB	....	6.0
HB	....	5.4
WR	5.4	7.3
HR	2.9	5.0
HIAxx	3.0	2.9
$WIIBrr_1$	4.0	3.8

crinus bakeri MOORE & PLUMMER, type species of this genus, and of typical representatives of *Exocrinus*, kindly furnished by HARRELL STRIMPLE, has convinced us that the species named *M. moorei* by us in 1966 should be re-allocated to *Exocrinus*. We believe that the two genera are closely related: both have a low dorsal cup, high axillary brachials and exotomously branching arms. The main differences are that the brachials of *Marathonocrinus* are relatively wider, shorter, and have a flat outer surface, and, more importantly, that nonaxillary as well as axillary brachials of *Marathonocrinus* are hyperpinnulate, whereas in *Exocrinus* only the high axillary brachials bear more than one pinnule.

This species is moderately common in the collection and complete or nearly complete crowns are more common than sets of arms; 27 specimens have been found. Study of the arms reveals that the IVAxx may be the third, fourth, or fifth quartibrach. One immature specimen with a dorsal cup 5 mm. in diameter has relatively larger infrabasals than more mature specimens and the *CD* basal is proportionately larger. The second secundibrach is elongate and axillary, indicating that fusion of proximal brachs to axils occurred at an early ontogenetic stage. All specimens consistently have the *B* and *E* primaxils shorter than primaxils of other rays. One specimen has two small anal plates next above anal *X*.

Illustrated hypotypes are nos. 45840 and 45841.

Family SPANIOCRINIDAE Moore & Laudon, 1943

Genus STUARTWELLERCRINUS Moore & Plummer, 1940

Type species.—Cibolocrinus turbinatus WELLER, 1909.

STUARTWELLERCRINUS CORBATOI Lane & Webster, 1966

Plate 2, figure 12

Stuartwellercrinus corbatoi LANE & WEBSTER, 1966, p. 37, pl. 8, fig. 1-9; fig. 11-14.

Ten additional specimens of this species have been found that provide new information about the infrabasal circlet and position of the anal *X*. One specimen (paratype 39705) is immature, has five unfused infrabasal plates, and displays two small anal plates on the upper surface of the anal *X*. Only two of the new specimens have the infrabasal circlet preserved so that the number and arrangement of plates can be determined. Both of these have three infrabasals, the small one located in the *C* radius like the holotype of *S. corbatoi*. Presumably fusion of infrabasals occurred late in the development of individuals of this species, and the number and position of sutures that were obliterated was variable. Three of the new specimens have the anal in contact with the posterior basal and two specimens have the anal almost out of the cup, notching the edges of the *C* and *D* radials and not in contact with the posterior basal. One specimen (hypotype 45842) has 24 mm. of stem preserved below the crown. The columnals are round and low next to the cup, becoming progressively higher distally and are almost as high as wide about 15 mm. below the cup. Nodals and internodals cannot be distinguished.

GENUS AND SPECIES UNKNOWN

SPECIES B

Plate 8, figure 5; Figure 4,*1*

Description.—Crown small; dorsal cup low cone-shaped, all plates smooth; infrabasal circlet pentagonal in outline, flat, tips of small infrabasals

EXPLANATION OF PLATE 5

FIGURE

1-2. *Elibatocrinus elongatus* WEBSTER & LANE, n. sp. Holotype (45827), *E*-ray view (*D* ray on right), fig. 2 showing proximal column, ×0.7 (p. 16).

3. *Perimestocrinus nevadensis* LANE & WEBSTER. Hypotype (45861), *D*-ray view (*C* ray to right) of crown (p. 30).

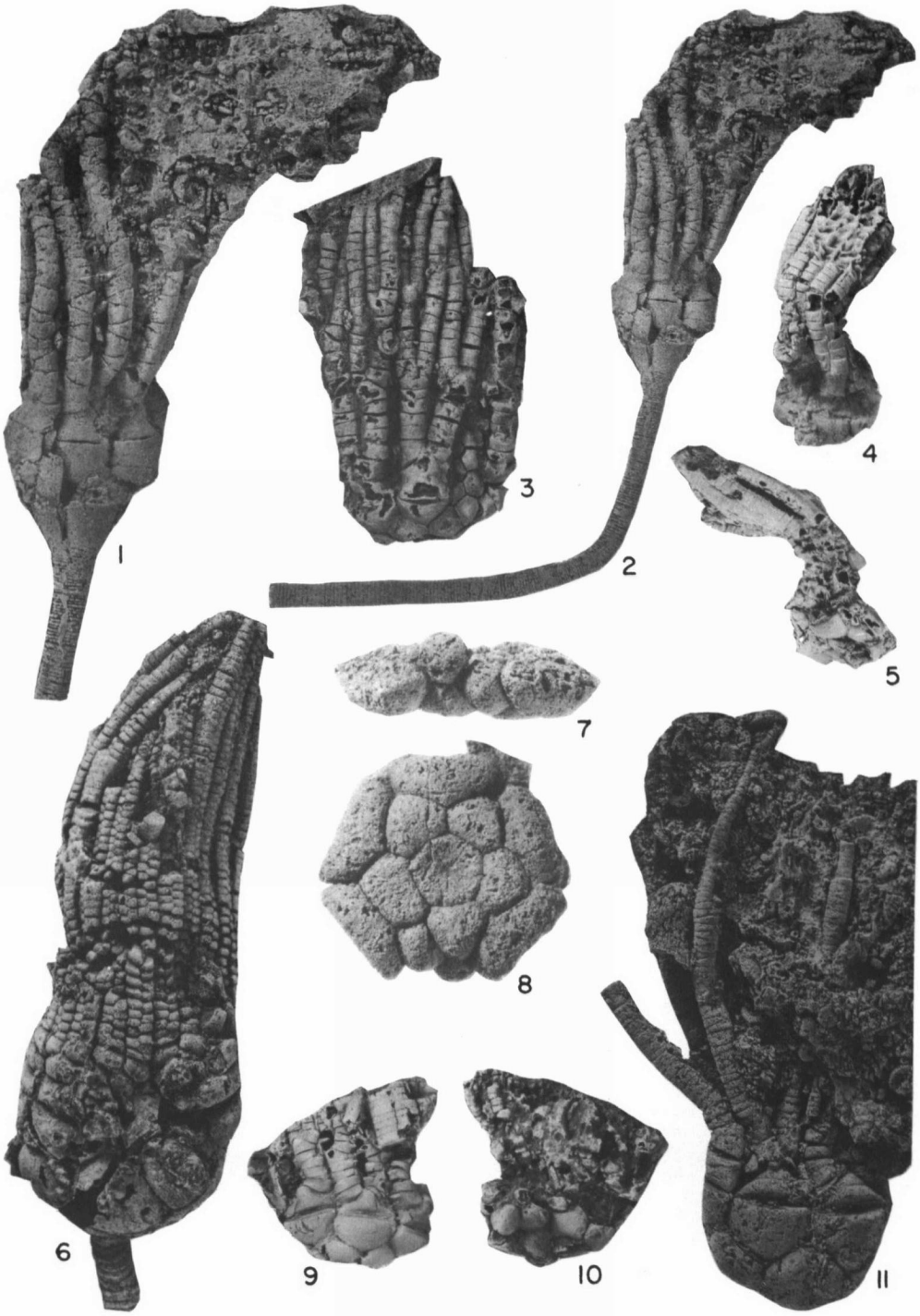
4-5. *Phanocrinus? insolitus* WEBSTER & LANE, n. sp. Holotype (45856), *B*-ray view (*A* ray to right) and *CD*-interray view (*C* ray to right) (p. 26).

6. *Parethelocrinus rectilatus* (LANE & WEBSTER), n. comb. Hypotype (45846), *CD*-interray view (*C* ray to right), ×0.7 (p. 22).

7-8. *Aatocrinus permicus* WEBSTER & LANE, n. sp. Holotype (45857), *CD*-interray view and basal view (*A* ray at top), (p. 27).

9-10. *Perimestocrinus oasis* WEBSTER & LANE, n. sp. Holotype (45862), *A*-ray view (*E* ray to right) and *CD*-interray view (*A* ray to extreme right) (p. 30).

11. *Polusocrinus amplus* (LANE & WEBSTER), n. comb. Hypotype 45864), *A*-ray view (*E* ray to right) showing regenerated distal parts of arms of *A* ray, ×0.7 (p. 31).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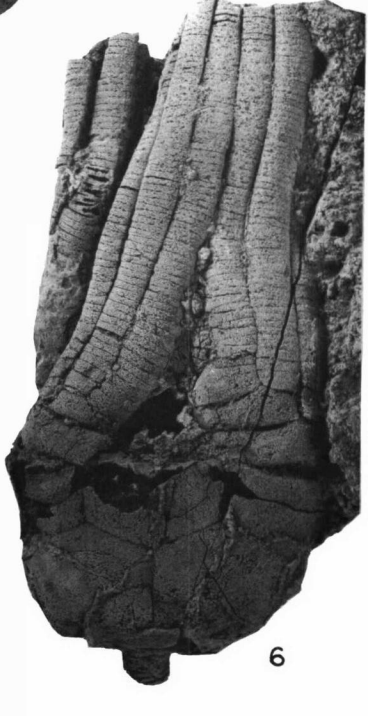

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barely visible in side view. Basals relatively large, flat, pentagonal in outline, posterior basal with long upper-right suture and short upper-left suture. Radials wider than high, gently convex; *C* radial with short lower-left suture and long lower-right suture. Number of anal plates unknown but probably two or three, based on sutures of posterior basal and *C* radial. Arms five, unbranched. First primibrachs wide, low, occupying full width of radial plates, gently convex transversely; second primibrach with subparallel upper and lower margins, third primibrach distinctly wedge-shaped; higher brachs arranged in syzygial pairs, with pinnule facet on upper edge of wide side of epizygal. Syzygial sutures perpendicular to edge of arm; sutures between pairs steeply inclined and alternating in direction of slope between adjacent pairs. Stem round, with distinct nodals and internodals.

Remarks.—The stem of the only known specimen of this species covers the posterior and *C*-ray areas of the cup, and plates in this area are out of place or missing. Arms of the *D* and *E* rays are in place up through the fifth primibrach and are then broken; lower parts of the arms of the other rays are not observed. Upper parts of arms showing distinctive syzygial pairs of brachials are preserved close to the cup and parts of three arms can be seen, but their ray orientation is not known.

Few Paleozoic crinoids have ever been observed that have syzygial sutures between brachials such as are commonly present in many articulate crinoids. The Mississippian genus *Corythocrinus* KIRK, 1946, is one of the few such Paleozoic crinoids known to us. None of the described Paleozoic genera with five unbranched arms is closely comparable to Species B. *Allosocrinus* and *Spaniocrinus* have a single anal in the cup, whereas we conclude that Species B must have had at least two, and possibly three, anal plates. *Cromyocrinus* has only five arms, but clearly is not related to the form discussed here. Because complete information on the cup cannot be obtained from the single known specimen we prefer not to make it the holotype of a new species, but to wait until more completely preserved specimens are available.

Material.—The hypotype is no. 45843.

Measurements.—Measurements on the hypotype are (in mm.): H, 3.9; W, 9.5 (est.); WS, 2.0; WIBB, 4.2; WIB, 2.4; HB, 2.4; WB, 4.7; HR, 2.8; WR, 4.7; $HIBrr_1$, 1.5; $WIBrr_1$, 4.6; $HIBrr_2$, 1.2; $WIBrr_2$, 4.0; $HIBrr_3$, 2.0; $WIBrr_3$, 3.8.

Family AGASSIZOCRINIDAE Miller, 1889

Genus PETSCHORACRINUS Yakovlev, 1928

Type species.—Petschoracrinus variabilis YAKOVLEV, 1928.

PETSCHORACRINUS? sp.

Plate 3, figures 7-8

Two infrabasal circlets are tentatively assigned to this genus. Both specimens have five high plates that curve in at the base to form a narrow concavity around a small stem impression closely resembling the infrabasal circlet of *Petschoracrinus variabilis*. Apart from an axillary brachial plate associated with one specimen, basals and all higher crown plates are missing on both specimens. One example is 14 mm. wide and 9 mm. high; the other is 9 mm. wide and 6.5 mm. high.

The illustrated hypotype is no. 45844, the other no. 45845.

Family ETHELOCRINIDAE Strimple, 1961

Genus PARETHELOCRINUS Strimple, 1961

Parethelocrinus STRIMPLE, 1961, p. 81. *Type species.—Parethelocrinus ellipticus* STRIMPLE, 1961.

Aglaocrinus STRIMPLE, 1961, p. 86. *Type species.—Ethelocrinus magnus* STRIMPLE, 1949.

Study by us of typical specimens of the two type species of *Parethelocrinus* and *Aglaocrinus* leads to the conclusion that these genera are synonymous. The type species of both have 16 arms arranged in identical manner. Although STRIMPLE

EXPLANATION OF PLATE 6

FIGURE

1-2. *Endelocrinus* sp. Hypotype (45854), *CD*-interray view (*B* ray to right) and *A*-ray view (*D* ray to far right), ×2 (p. 25).

3. *Erisocrinus longwelli* LANE & WEBSTER. Hypotype (45851), view of crown and proximal part of column (p. 23).

4-5. *Arroyocrinus popenoei* LANE & WEBSTER.——4. Hypotype (45848), *A*-ray view (*E* ray to right).——5. Hypotype (45869), *A*-ray view (*E* ray to right), ×0.75 (p. 22).

6. *Aesiocrinus nodosus* WEBSTER & LANE, n. sp. Holotype (45865), *CD*-interray view (*C* ray to right) (p. 31).

(1961) cited differences in cup ornament and degree of suture impression as diagnostic characters of generic importance, it is reasonably clear from his illustrations (*op. cit.*, 1961, pl. 8, fig. 1, 5) that the sutures are impressed to about the same degree in both species. One species *(A. magnus)* is said to have mildly nodose ornament, the other *(P. ellipticus)* is reported to have granular ornament. We judge this distinction to be of specific rather than generic importance, and so place the two genera in synonymy.

PARETHELOCRINUS RECTILATUS (Lane & Webster), 1966, n.comb.

Plate 5, figure 6

Aglaocrinus? rectilatus LANE & WEBSTER, 1966, p. 39, pl. 7, fig. 3-4, 7.

One additional specimen, a large slightly crushed crown, of *Parethelocrinus rectilatus* has been found since the species was first described. This specimen has an infrabasal circlet that is subhorizontal proximally, with slight recess for column attachment, and upflaring distally with tips of infrabasals visible in side view. There are 18 arms arranged as in the holotype. A single, slender pinnule, composed of narrow, elongate pinnulars, is joined to each brachial. Column round, made up of alternating nodals and internodals, former about twice as high as latter, and gently convex externally; articular surfaces are radially crenulate.

The anterior two arms of the *B* ray, all branches of the *D* ray, and the posterior arm of the *E* ray have been broken off and regenerated. Arms of the *D* ray were broken more proximally than on the other two rays, and are both narrower and shorter, suggesting that regeneration was not complete when the individual died.

Parethelocrinus rectilatus has 18 or 19 arms, rather than the 12 to 16 arms of Pennsylvanian species of the genus, and is judged to have evolved from a Pennsylvanian or Early Permian form by adding arm branches in the *B* and *E* rays. The increase in number of arms is not considered to be of generic significance.

The hypotype is no. 45846.

GENUS UNKNOWN

SPECIES C

Plate 4, figures 10-11

Description.—Crown large, expanded upward, with maximum width at mid-height of arms. Dorsal cup crushed, incomplete, probably low bowl-shaped with distinct but shallow basal concavity. Infrabasals not preserved. Basals hexagonal, abruptly curved in along proximal edges to form edge of basal concavity. Radials wider than high, facets do not occupy full width of plates; narrow radial notch present. Posterior basal truncate above for contact with large anal *X* that projects out of the cup. First primibrachs axillary in all rays; first secundibrachs axillary in some rays. Four arms in *D* ray; minimum of 12 arms are preserved, and probably 14 to 16 arms were originally present. Brachials biserial, strongly rounded externally, with coarse pinnules. Anal sac elongate, broadly rounded by distal tip, extending to about one-half the height of the arms, composed of 6 rows of large hexagonal tumid plates; distinct pores between sides of adjacent plates.

Remarks.—Presence of more than ten biserial arms that branch on lowest primibrachs and secundibrachs indicate relationship of this genus and species with the Ethelocrinidae. Species C is more advanced than any described ethelocrinid in having only a single anal plate in the cup and is judged to have evolved from a Pennsylvanian ethelocrinid like *Parethelocrinus*. The strongly rounded arms are unlike the wide, flat biserial arms of most erisocrinids. The cup of the single known specimen is incomplete and crushed, so it cannot serve as a satisfactory holotype for a new species, which we believe the specimen to represent.

Material.—The hypotype of Species C is no. 45847.

Measurements.—Measurements on the hypotype are (in mm.): HC, 95 (incomplete); HB, 8.2 (approx.); WB, 8.8 (approx.); WR, 12.5; $HIBrr_1$, 5.0; $WIBrr_1$, 11.0.

Genus ARROYOCRINUS Lane & Webster, 1966

Type species.—Arroyocrinus popenoei LANE & WEBSTER, 1966.

ARROYOCRINUS POPENOEI Lane & Webster, 1966

Plate 6, figures 4-5; Plate 7, figure 2

Arroyocrinus popenoei LANE & WEBSTER, 1966, p. 41, pl. 9, fig. 1-6; fig. 15-17.

This is the second most common species of crinoid in the fauna, after *Moapacrinus rotundatus*, and 83 specimens, most of them arm fragments, have been found so far. These specimens exhibit considerable variation in several parts of

the crown that led us to consider whether more than one species was represented. However, some variation can be attributed to different maturity of individuals, and intergrading of other differences support the conclusion that only one quite variable species is represented.

Specimens with 13 through 17 arms have been found, and one specimen questionably has only 12 arms. Among individuals on which the total number of arms could be counted, two specimens have 13 arms; seven, 14 arms; two have 15 arms; 11, 16 arms; and one specimen has 17 arms. Sixteen-armed crinoids have four arms in the *C* and *D* rays, three each in the *B* and *E* rays, and two in the *A* ray. The 17-armed individual has an additional arm in the *C* ray. All specimens with three arms in the *B* and *E* rays consistently have a single arm above the posterior half, and two arms above the anterior half, of the primaxil. Fourteen-armed specimens have three arms in all but the *A* ray, and 13- and 15-armed specimens have only two arms in either the *B* or *E* ray, and three or four arms in the *C* and *D* rays.

One large new crown is unusual in having a normal large radial plate in the *A* ray, but no brachials developed above it, probably because of injury. Arms of adjacent *B* and *E* rays close in above the *A* radial and are laterally abutting. The space directly above the radial is partly filled with small perisomatic plates that apparently closed off open space normally occupied by *A*-ray arms. Because of this abnormality the anterior aspect of the crown is superficially similar to the posterior aspect. The specimen has a normal complement of 16 arms, five in the *C* and *D* rays and three in the *B* and *E* rays.

Another variable feature is the external configuration of brachials. Some specimens have brachials that are slightly wedge-shaped or cuneate, whereas others have parallel upper and lower edges. Cuneate brachs are developed to a somewhat greater degree in small individuals and in distal arm parts of larger individuals. Therefore, we judge the change from a cuneate to a rectangular brach outline to be at least partly a growth phenomenon. Brachs also exhibit conspicuous increase in width with growth, but do not appreciably increase in height. Both large and small individuals have about 16 to 19 brachs in 20 mm. along an arm, although the brachs of a mature specimen may be more than twice as wide as those of a small specimen.

In the originally described specimens of this species the large radianal extends completely across the posterior interray, touches the *D* radial and separates the anal *X* from posterior basal. One new specimen has a proportionately smaller radianal that does not touch the *D* radial and the anal *X* has a narrow, less than 1 mm. wide, suture with the posterior basal. Another large partial crown has the radianal as the only anal plate in the cup, directly above the posterior basal and with the anal *X* and right tube plate on top of the radianal but out of the cup. This specimen agrees in all other respects with typical *Arroyocrinus* and the difference in number of anal plates in the cup is judged to be an infraspecific difference. The latter specimen, with a single anal in the cup, bears close resemblance to a species from Timor called *Synyphocrinus trautscholdi* WANNER, 1923. This species may be closely related to *Arroyocrinus*.

In the initial description it was stated that the infrabasal circlet was flat or gently concave. Additional specimens indicate that the base is gently convex and that the tips of the infrabasals are visible in side view.

Illustrated specimens are hypotypes no. 45848, 45849, and 45869.

Family ERISOCRINIDAE Miller, 1889

Genus ERISOCRINUS Meek & Worthen, 1865

Type species.—Erisocrinus typus MEEK & WORTHEN, 1965.

ERISOCRINUS LONGWELLI Lane & Webster, 1966

Plate 1, figure 13; Plate 6, figure 3

Erisocrinus longwelli LANE & WEBSTER, 1966, p. 43, pl. 10, fig. 1-3, 5-6.

Erisocrinus longwelli is the third most abundant species found at Battleship Wash; a total of 59 specimens have been collected. A newly discovered crown (hypotype no. 45851) and a partial crown (paratype no. 40442) are the only specimens with part of the column attached; both have nearly 2.5 cm. of stem preserved. The column is round and consists of alternating nodals and internodals; nodals are slightly wider and about twice as high as internodals, and are slightly convex on outer edges, whereas internodals have straight outer surfaces. On the larger crown every fifth

nodal is higher, slightly wider, and more strongly convex than intervening nodals, whereas the paratype shows only a faint suggestion of this feature. The axial canal is round.

Study of the ventral surface of the dorsal cup of an immature and a mature individual shows no discernible notch for an anal plate between any of the radials.

Arm fragments of this species can be distinguished from those of *Delocrinus vastus* only by careful study. The brachials of *Erisocrinus longwelli* are somewhat narrower, have a more angular inner tip, and a flatter exterior surface. A partial crown of *E. longwelli* has one arm which was broken a short distance above the lowest secundibrachs and then regenerated. The regenerated part is considerably narrower and shorter than the other arms.

Genus DELOCRINUS Miller & Gurley, 1890

Type species.—*Poteriocrinus hemisphericus* SHUMARD, 1858.

DELOCRINUS VASTUS Lane & Webster, 1966

Plate 8, figure 6

Delocrinus vastus LANE & WEBSTER, 1966, p. 45, pl. 12, fig. 1-2, 5.

Remarks.—A fragmentary slightly crushed crown of *Delocrinus vastus* shows that there is a deep narrow basal concavity in this species. Although dislocated, the infrabasal circlet is present, downflaring, and confined to the top of the concavity. The basal concavity is not discernible on the holotype and paratype because of crushing. Study of several sets of arms shows some variation in the nature of secundibrach 2. It is a uniserial plate in some cases and a biserial one in others, and both conditions may exist in different rays of the same specimen. Even where it is the first biserial element of any ray it is wider than any succeeding brachial, commonly extending one-half to two-thirds the width under the third secundibrach.

The illustrated hypotype is no. 45852.

Genus ENDELOCRINUS Moore & Plummer, 1940

Type species.—*Eupachycrinus fayettensis* WORTHEN, 1873.

The genus *Endelocrinus* was proposed by MOORE & PLUMMER (1940) for delocrinoids with bulbous basals and radials that have distinctly impressed sutures, or depressions at the angles where these plates meet, or both. STRIMPLE (1961) proposed to separate smooth and ornamented *Endelocrinus* into two genera, establishing *Corythocrinus* for nodose species, and later (1962a) proposing the substitute name *Tholiacrinus* because the name *Corythocrinus* was preoccupied. Because it has never been established that the smooth and ornamented species belong to two distinct lineages, or that nodose forms could not have evolved several times from smooth forms, or vice versa, we judge ornament alone to be an unsatisfactory character for generic distinction among this group of crinoids. We therefore consider *Tholiacrinus* to be a synonym of *Endelocrinus*.

ENDELOCRINUS TORUS Webster & Lane, n. sp.

Plate 4, figures 4-6; Figure 4,*3*

Description.—Dorsal cup large, medium truncate bowl-shaped; deep basal invagination; base flattened; sides slightly outflaring, becoming vertical in distal parts. Infrabasal circlet not visible. Basals five, wider than high, strongly recurved longitudinally, slightly tumid transversely, proximal ends forming major part of invagination only a short distance below level of distal tips, distal tips moderately incurved to form shallow dimple at angles with adjacent radials, surface covered

EXPLANATION OF PLATE 7

FIGURE

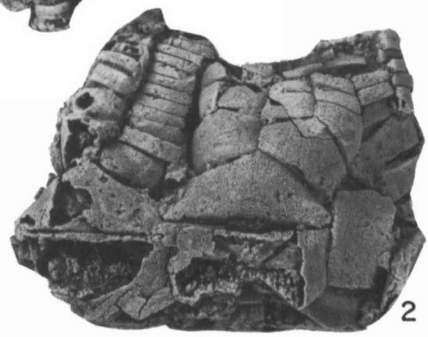
1, 5. *Texacrinus distortus* WEBSTER & LANE, n. sp. Paratype (45838), *CD*-interray view (*C* ray to right) and *A*-ray view (*E* ray to right) of crushed crown (p. 19).

2. *Arroyocrinus popenoei* LANE & WEBSTER. Hypotype 45849), *D*-ray view (*C* ray to right) showing large single anal plate within radial circlet (p. 22).

3. *Neozeacrinus wanneri* WEBSTER & LANE, n. sp. Paratype (45859), basal view (*E* ray at top) of crushed partly disarticulated crown, ×0.75 (p. 27).

4. *Neozeacrinus coronulus* WEBSTER & LANE, n. sp. Holotype (45860), basal view (*A* ray at top) of crushed partly disarticulated crown (p. 28).

1



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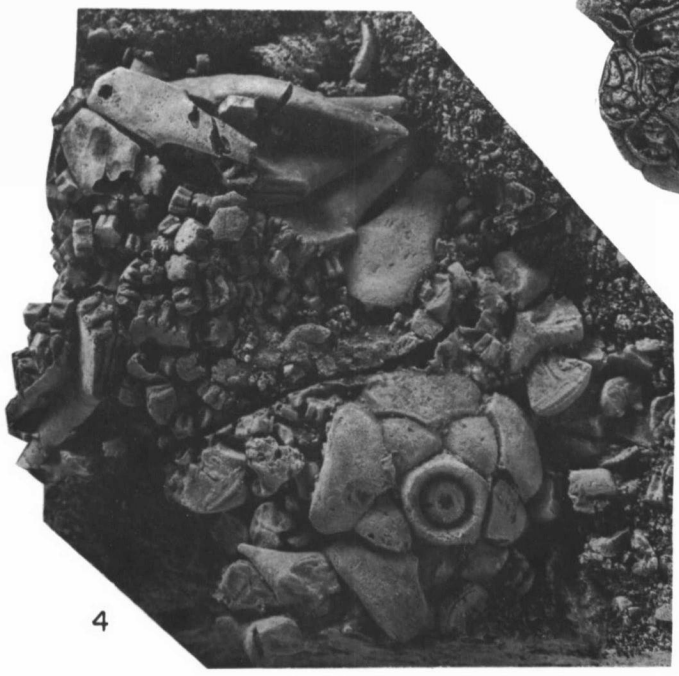
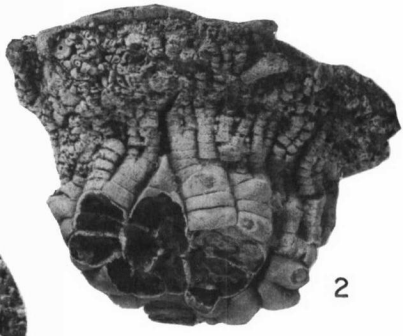


4

5


1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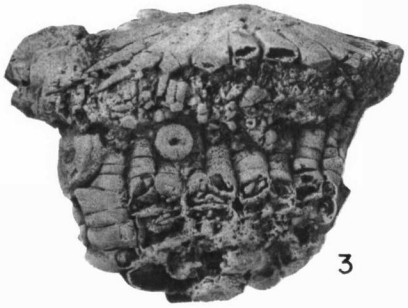
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4


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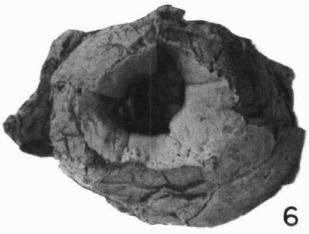
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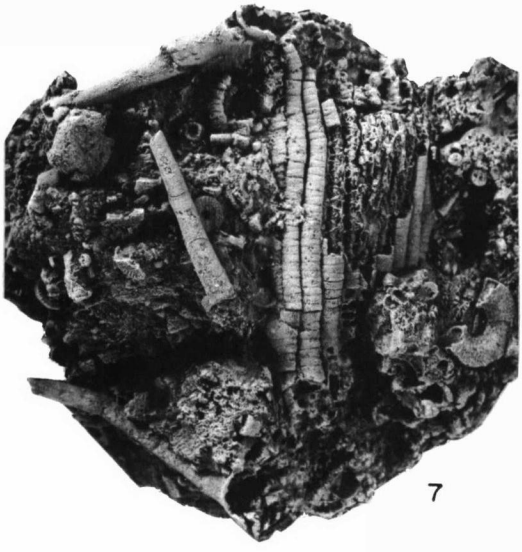
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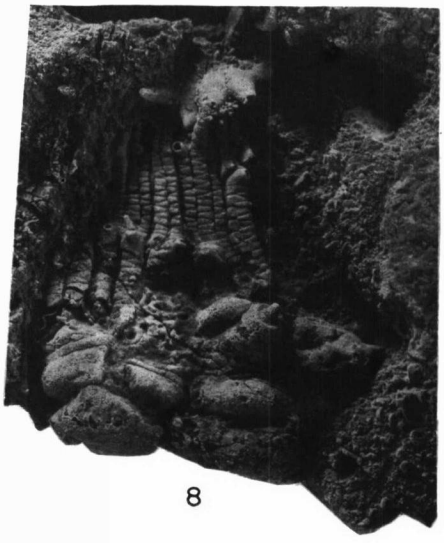
8

with numerous randomly placed coarse nodes; posterior basal flattened on distal tip for reception of anal *X*. Radials five, pentagonal, moderately tumid, nearly twice as wide as high, proximal tips inflared to form dimple at angles with subjacent basals, surface covered with numerous nodes, some of which coalesce to form short irregular hummocky ridges. Radial facet wide, deep, with slight outward slope; outer ligament area moderately deep, horizontal, as wide as radial; outer ligament ridge denticulate, coalesces with transverse ridge on distal tips; ligament pit furrow shallow, extends dorsally across ligament pit, half as long as radial is wide; ligament pit central, deep, 1.7 mm. long, slopes ventrally under transverse ridge; transverse ridge denticulate, as wide as radial; inner ligament area divided into two mirror-image halves by broad shallow intermuscular furrow; no central pit; lateral furrow distinct, with steep walls, grades into intermuscular furrow ventrally; oblique ridge not distinct, grades into muscle area; muscle area smooth, grades into intermuscular furrow. No primibrachs preserved. Associated secundibrachs uniserial, approximately three times as wide as high, ornamented with two low longitudinal ridges, one each near the lateral extremities; all higher secundibrachs biserial, slightly convex transversely and longitudinally.

Remarks.—The above description is based on a dorsal cup with associated crushed arm fragments. *Endelocrinus torus* is easily distinguished from all previously described species because of larger size of the individual and coarse ornamentation.

Name.—The species name *torus* is Latin meaning round elevation, in reference to the ornamentation.

Material.—A single specimen is holotype no. 45853.

Measurements.—The measurements of the holotype are (in mm.): H, 13.8; W, 30.7; HW ratio 0.45; depth basal invagination (approximate) 6.6; HB, 11.0; WB, 13.7; HR, 9.7; WR, 17.2; H anal *X*, 7.4; W anal *X*, 5.3; HIIBrr$_1$, 2.8; WIIBrr$_1$, 8.0.

ENDELOCRINUS sp.

Plate 6, figures 1-2

Description.—Crown small, cylindrical; dorsal cup low bowl-shaped, with pronounced basal concavity; all cup plates smooth. Infrabasal circlet not visible in side view; basals forming edge of basal concavity, curving abruptly upward to form lower half of cup side, upper angles of basals depressed just below interradial sutures; radials wider than high, gently convex, proximal tips depressed; radial facets filling distal radial surfaces. Posterior basal narrowly truncate above for contact with single hexagonal anal *X* that has its proximal one-half in cup; single anal plate directly above anal *X*. Ten arms, first primibrachs axillary, high, gently convex transversely, protruding outward just below apex; secundibrachs preserved up to secundibrach *12*, uniserial and relatively large below, becoming lower and more strongly cuneate distally; highest preserved secundibrachs biserially arranged. Stem and anal sac unknown.

Remarks.—The small size, depressed angles of basals and radials, prominent basal concavity, single anal plate, and tendency of the brachials to become biserial relatively high above the cup, all ally this crinoid to *Endelocrinus*. We judge the specimen to be unsatisfactory as a holotype for a new species. The cup and primibrachs of *Endelocrinus* sp. are comparable to *E. grafordensis* Moore & Plummer (1940), but the arms differ in beginning of the biserial condition relatively higher above the cup. This species is not closely comparable at all to *E. torus* in the same fauna which has a much larger cup and rugose ornament.

Material.—The only known specimen is hypotype no. 45854.

EXPLANATION OF PLATE 8

Figure

1-4. *Neozeacrinus wanneri* Webster & Lane, n. sp. Holotype (45858), views of oral surface of tegmen, *CD* interray (*B* ray to right), *A* ray (*E* ray to right), and base (*B* ray to left) (p. 27).

5. Genus and Species unknown, Species B. Hypotype (45843), basal view of slightly disarticulated crown, ×2 (p. 20).

6. *Delocrinus vastus* Lane & Webster. Hypotype (45852), basal view (*A* ray at top) showing deep absal concavity (p. 24).

7. *Plaxocrinus* sp. Hypotype (23683), side view of partial crown (p. 29).

8. *Schedexocrinus* sp. Hypotype (45863), side view of partial crown (p. 30).

Measurements.—Measurements taken on the hypotype are (in mm.): HC (incompl.), 26; W (approx.) 11; H, 7.3; WB, 5.5; WB, 4.0; WR, 6.6; HR, 4.0; HIAxx, 4.1; WIIBrr$_4$, 2.9.

Genus GRAPHIOCRINUS de Koninck & Lehon, 1854

Type species.—*Graphiocrinus encrinoides* DE KONINCK & LEHON, 1854.

GRAPHIOCRINUS SCOPULUS Lane & Webster, 1966

Plate 4, figures 1-3

Graphiocrinus scopulus LANE & WEBSTER, 1966, p. 46, pl. 10, fig. 4, 8.

One additional specimen of *Graphiocrinus scopulus* consisting of a dorsal cup with arms preserved through the sixth secundibrachs has been found. The specimen is considerably larger than either of the primary types, indicating that the holotype, and possibly the paratype, may be somewhat immature. The new specimen agrees closely in morphology with the original specimens and no ontogenetic changes, other than relative proportions of plates, can be observed. The hypotype is no. 45855.

Measurements on the hypotype are (in mm.): W, 24; H, 11; WIBB, 7; WB, 10.2; HB, 6.8; WR, 14.3; HR, 8.0; HIAxx, 4.7.

Genus PHANOCRINUS Kirk, 1937

Type species.—*Zeacrinus formosus* WORTHEN, 1873.

PHANOCRINUS? INSOLITUS Webster & Lane, new species

Plate 5, figures 4-5

Description.—Crown small, narrow, cylindrical. Dorsal cup low bowl-shaped, probably with flat or gently concave base. Infrabasals small, mostly covered by stem, basals gently convex, radials slightly tumid, sutures impressed, all plates smooth; radial facets occupying full width of radials. Three small anal plates in cup; radianal small, tumid, pentagonal, directly on top of posterior basal and supporting anal *X* on left and right tube plate on right. First primibrach axillary in all rays, supporting ten uniserial arms; brachs quadrangular in outline, about twice as wide as high, maintaining almost constant width high above cup. Anal sac and stem not known.

Remarks.—Relatively few Pennsylvanian or Permian crinoids have been described that have a low, bowl-shaped cup, three anal plates in the cup, and ten uniserial arms that branch on first primibrachs. *Dicromyocrinus* has a configuration of cup and arms that is quite unlike the small specimen described here. *Scytalocrinus* and *Phanocrinus*, both common Mississippian genera, seem to be most like *P.? insolitus*, and the new species is referred tentatively to the latter genus because of close similarity of the arms. *Phanocrinus* has never been reported from rocks other than Upper Mississippian, and the resemblance of our specimen to this genus may be an instance of homeomorphy. Until more and better-preserved specimens are found the generic assignment of this species will remain in doubt.

Name.—The specific name *insolitus* is Latin meaning unusual or strange, in allusion to the occurrence of this form in the Permian.

Material.—The only known specimen, the holotype, is no. 45856.

Measurements.—Measurements on the holotype are (in mm.): HC, 38.8 (approx.); $W_{max.}$, 16.3; $W_{min.}$, 10.9; $W_{av.}$, 13.6; HB, 3.6; WB, 4.5; HR, 4.6; WR, 7.0; HIBrr$_1$, 4.9; WIBrr$_1$ (approx.), 5.6; HIIBrr$_1$, 2.7; WIIBrr$_1$, 3.7.

Family PIRASOCRINIDAE Moore & Laudon, 1943

The Pirasocrinidae consist mostly of Pennsylvanian genera, all with a low, discoid cup which contains three anal plates. Many of the genera were described by MOORE & PLUMMER (1938, 1940) and STRIMPLE (1961). Several of the earlier described genera were based primarily on dorsal cups, arms being incomplete or unknown. Relatively slight differences in cup morphology were used to differentiate genera, such as degree of concavity of the cup base, the degree to which sutures were impressed, and convexity of cup plates. Consequently, in order to identify new pirasocrinids at the generic level firmly it is usually necessary to have numerous well-preserved specimens. It is probable that revision of the family would result in placing several genera in synonymy.

Permian pirasocrinids from Nevada are an especially difficult group to study because we have been able to collect relatively few specimens and none of them is adequately complete or especially well-preserved. They are quite diverse in appearance, however, with the result that we have placed

a total of 19 specimens assigned to the family in 5 genera. It is possible that further collecting may yield enough additional specimens to show that some of the differences we observe are gradational and that fewer taxa than we report here are represented in the fauna.

Genus AATOCRINUS Moore & Plummer, 1940

Type species.—Zeacrinus? robustus Beede, 1900.

AATOCRINUS PERMICUS Webster & Lane, new species

Plate 5, figures 7-8

Description.—Dorsal cup discoid, large, hexagonal when viewed from above or below, sutures impressed, with wide shallow basal concavity and distinct notch on posterior side. Five infrabasals, dart-shaped, as wide as long, circlet pentagonal in outline, subhorizontal to slightly downflaring, nearly covered by large, round radially crenulate stem impression, not visible in side view; five basals large, pentagonal except *BC* and *CD* basals which are hexagonal, slightly wider than high, strongly tumid, proximal part slightly downflared, distal tips upflared and visible in side view; interbasal sutures short; five radials hexagonal large, strongly tumid, nearly twice as wide as high, very thick, with distinct radial notch, facets not occupying full width of radials, strongly sloping outward at 32°. Three anals in cup; radianal five-sided, strongly tumid, in contact with *C* radial, *BC* and *CD* basals, anal *X* and right tube plate; anal *X* less than half below radial summit, strongly tumid, adjoined by radianal, *CD* basal, *D* radial, probably *D* ray primibrach, two tube plates and right tube plate. Right tube plate not present but notch for proximal end below radial summit. *D*-ray primibrach only one present, large, strongly tumid, nearly twice as wide as high, axillary.

Remarks.—Previously described species of *Aatocrinus* are reported only from strata of Desmoinesian and Missourian age of the midcontinent region. *A. permicus*, n. sp., is most similar to the type species of the genus, *A. robustus* (Beede). *A. permicus* has a shallower basal concavity, however, strongly tumid anal plates, and a much larger infrabasal circlet relative to cup size.

Name.—Because this is the first species of *Aatocrinus* reported from Permian-age rocks it is designated *permicus*.

Material.—The holotype and only known specimen is no. 45857.

Measurements.—Measurements on the holotype (in mm.) are: H, 11.5; W, 37; H/W ratio, 0.31; WIBB, 11.2; WIB, 6.1; HIB, 6.1; HB, 8.9; WB, 11.0; HR, 9.8; WR, 19.3; $HIBr_1$, 8.7; $WIBr_1$, 15.7.

Genus NEOZEACRINUS Wanner, 1937

Type species.—Neozeacrinus peramplus Wanner, 1937.

We recognize four species in the genus: *Neozeacrinus peramplus* Wanner, *N. uddeni* (Weller), *N. wanneri* Webster & Lane, n. sp., and *N. coronulus* Webster & Lane, n. sp. Restricted in this way the genus consists of exclusively Permian species, all but one of which has been demonstrated to have hyperpinnulate brachials. *N. uddeni* was reallocated from *Hydreionocrinus* by Moore & Plummer (1940), and subsequently assigned to *Plaxocrinus* by Strimple (1961). Only the dorsal cup, and some questionably assigned tegmen spines, are known for this species, but the cup is closely comparable to that of the other three species assigned to the genus by us.

NEOZEACRINUS WANNERI Webster & Lane, new species

Plate 7, figure 3; Plate 8, figures 1-4; Figure 4,4-5

Description.—Crown low, wide, capped with spine-bearing tegmen ring, arms uniserial, isotomous proximally, bi-endotomous distally, hyperpinnulate. Dorsal cup subdiscoid, probably hexagonal in basal view, with shallow basal concavity, impressed sutures, and faint radial notches. Infrabasal circlet wide, subhorizontal, mostly covered by impressed round column; five wide dart-shaped infrabasals, slightly tumid in distal parts, only distal tips visible around proximal columnal, not visible in side view except distal tip of truncated *C* infrabasal. Basals wider than high, subtrigonal in outline except for quadrangular posterior basal, tumid, interbasal sutures reduced nearly to points of angles, proximal end forming part of basal concavity, distal tips upflaring, visible in side view. Radials half again as wide as high, outflaring, tumid, distal end nearly vertical in side view; radial facets downflaring at nearly 40°, nearly as wide as full width of radial, but notch present. Posterior interradius wide; three anals in cup, radianal in contact with right tube plate, *C* radial,

BC basal, *C* infrabasal, *CD* basal, and anal *X*, which is nearly as wide as high, about one-half below radial summit; right tube plate less than half below radial summit. Three anal tube plates gradually taper upward between *C* and *D* rays, covered by tertibrachs of *C* ray and quartibrachs of *D* ray; uppermost of three tube plates triangular in outline, with pronounced longitudinal keel.

Primibrachs axillary in all rays, with width nearly twice height, distal apices projecting as short blunt horizontally directed spines. Higher brachs moderately convex, becoming strongly convex distally, hyperpinnulate distally, with two pinnules on each side. Arms interlocking proximally, branching isotomously on primibrach *1* and again on secundibrach *1* to *3*; at least two higher bi-endotomous divisions on tertibrach *3* to *8* and quartibrach *5* or *6*. All axils of isotomous divisions have short blunt horizontally directed spine shortly below distal apex; spines longer on secundibrachs; axils of endotomous branchings may or may not be spinose; arms reaching lateral edges of spined tegmen ring. Tegmen cap consisting of an outer ring of laterally directed spines surrounding numerous polygonal cap plates; spines flat, elongate, in lateral contact nearly one-half length, 21 on holotype.

Remarks.—*Neozeacrinus wanneri* is closely similar to other described species of the genus, *N. peramplus* and *N. uddeni*. *N. wanneri* shows the same wide posterior interradius and arm arrangement as in *N. peramplus* but differs in being larger and in having spinose primibrachs and axillary secundibrachs. The dorsal cup of *N. wanneri* is smaller, has shorter interbasal sutures, and a wider radianal-infrabasal suture than *N. uddeni*. Tegminal spines which WELLER (1909) stated probably belong to *N. uddeni* have proportionately shorter lateral sutures and longer spines than those of *N. wanneri*.

The terminal end of the anal sac is unknown in the type species although the visible distal end is robust and probably had a spine ring similar to that described for *N. wanneri*.

Paratype no. 45859 is abnormal in having an extra plate within the radial circlet between the *A* and *E* rays. This plate is considerably narrower and shorter than a normal radial, is on top of the truncated *AE* basal, and is faceted. The facet slopes outward at an angle of nearly 70°, as compared to 40° for the adjacent radials. Cup plates of the paratype are not as tumid as those of the holotype. The paratype is a much larger individual and the less tumid cup plates may be a result of loss of tumidity with growth, or this may be intraspecific variation.

TABLE 6.—*Measurements of* Neozeacrinus wanneri WEBSTER & LANE, *new species*.

Abbreviations	Holotype 45858	Paratype 45859
HC	36.3	.....
H	5.3	10.6
W_{max}	24.0	40.0
W_{min}	14.4[a]	37.0
WIBB	9.1	14.5
WS	7.4	10.0
WIB	5.3	6.7
HB	5.0	10.5
WB	6.3	11.9
HR	6.7	10.0
WR	10.5[a]	19.3
$HIBrr_1$	3.5	4.2
$WIBrr_1$	10.9	18.4[a]
$HIIBrr_1$	3.5	4.2
$WIIBrr_1$	8.6	13.2
$HIIBrr_2$	4.1	7.2
$WIIBrr_2$	8.0	8.4
$HIIBrr_3$	2.5	.....
$WIIBrr_3$	5.4	.....

[a] Estimated.

Name.—This species is named in honor of JOHANNES WANNER in recognition of his work on the Permian crinoids of Timor.

Material.—A somewhat weathered crown is the holotype, no. 45858; the paratype, no. 45859, is a crushed, partly disarticulated crown.

Measurements.—See Table 6.

NEOZEACRINUS CORONULUS Webster & Lane, new species

Plate 7, figure 4

Description.—Dorsal cup low bowl-shaped to subdiscoid, sutures impressed, plates smooth, tumid. Infrabasals deeply recessed in center for reception of stem, with raised rim around stem impression; slightly upturned distally with tips of plates and rim visible in side view. Basals spear-shaped, tumid, with short interbasal sutures; posterior basal irregularly pentagonal, *BC* basal four-sided, other basals almost trigonal. Radials wider than high, evenly convex, *B* and *C* radials in contact with infrabasals; radial facets slightly narrower than radials, separated by narrow radial

notches, facets strongly inclined outward. Three tumid anal plates in cup; radianal elongate, in contact with infrabasals and *BC* basal; anal *X* directly above *CD* basal. Primibrachs not preserved. Brachs wide, low, gently rounded externally; four pinnules to each brach; all observable axillary brachs produced into prominent laterally directed spines that occupy entire external surface. Pattern of arm branching unknown.

Tegmen with large, wide cap ringed by flattened elongate spinose plates, ten of which are preserved; spines elliptical in cross section, with tips directed obliquely downward. Polygonal plates filling center of tegmen cap with two narrow slits along each sutural edge that expand in size inward; slits on inner edges of spinose plates with fine, dendritic pattern externally.

Remarks.—This species agrees with the type species of *Neozeacrinus*, *N. peramplus*, in having the radianal in contact with the infrabasal circlet and four pinnules to a brachial. Several dissociated brachs next to the cup show the inner edges of these plates and four distinct pinnular facets can be seen on them. The new species differs from the associated *N. wanneri* in having a distinctive rim on the infrabasals, more tumid cup plates, highly spinose axils, and in having two radials and the radianal in contact with the infrabasals.

Name.—The new species name *coronulus* is from the Latin dimunitive of *corona*, crown, rim, or border, in reference to the rim on the infrabasals.

Material.—A single specimen consisting of dorsal cup, disarticulated arms, and tegmen cap, is the holotype no. 45860.

Measurements.—Measurements on the holotype are (in mm.): H, 5.4 (est.) H (est.), 5.4; W, 32.5 W (approx.), 32.5; WS, 6.5; WIBB, 12.1; WIB, 6.9; HB, 7.8; WB, 9.5; HR, 8.8; WR, 17.6.

Genus PLAXOCRINUS Moore & Plummer, 1938

Type species.—*Hydreionocrinus crassidiscus* Miller & Gurley, 1894.

PLAXOCRINUS PIUTAE Lane & Webster, 1966

Plaxocrinus piutae Lane & Webster, 1966, p. 49, pl. 8, fig. 10-13.

Nine specimens of *Platocrinus piutae* are now known. Two recently discovered specimens show the distal part of the arms. At least nine endotomous arm divisions occur above the isotomous branching on the primibrachs. Endotomous axils are secundibrach *4* and tertibrach *6* in three specimens. Thereafter, some variation is noted, either every sixth or eighth brachial is axillary. In one specimen the branching on every sixth brach continues through octibrach *6*, which is then succeeded by two divisions on the eighth brach. On paratype no. 39651 the division on every eighth brach commences on quartibrach *8*. Nine endotomous branchings result in ten arms in each half ray, or 100 arms for the individual if all rays branch equally. All nonaxillary brachs are cuneate and have a single pinnule attached to the higher side. Variation in the presence or absence of short spines on the axillary brachs is common and rarely nonaxillary brachs may have a short, blunt laterally directed spine.

PLAXOCRINUS sp.

Plate 8, figure 7

One specimen originally classified as a paratype of *Plaxocrinus piutae* may represent a different, possibly new, species of this genus. Only the arms and tegmen cap are preserved on the specimen and these differ from *P. piutae* in having narrower brachials, more widely spaced endotomous divisions, and long slender spines on distal axils. The axillary primibrachs are produced into highly elongate, oblique, distally directed spines. The tegmen cap is composed of a ring of eight or nine highly spinose plates, the spinose part being three to four times longer than the nonspinose part of each plate. About 15 small, flat polygonal plates fill the center of the cap. This specimen may represent an intraspecific variant of *P. piutae* but until more specimens are known we prefer to emphasize its distinctiveness by setting it apart from that species.

The hypotype is no. 23683 (paratype of *Plaxocrinus piutae* Lane & Webster, 1966, p. 50). Measurements on the hypotype are (in mm.): L, most completely preserved primibrach, 37; W, same plate just above radial, 14; maximum L of most completely preserved tegmen spine-bearing plate, 36; maximum W, same plate, 10; L, spinose part of same plate, 28; L, nonspinose part of same plate, 8.

Genus PERIMESTOCRINUS Moore & Plummer, 1938

Type species.—Hydreionocrinus noduliferous Miller & Gurley, 1894.

PERIMESTOCRINUS NEVADENSIS Lane & Webster, 1966

Plate 5, figure 3

Perimestocrinus? nevadensis Lane & Webster, 1966, p. 51, pl. 12, fig. 7-8.

Discovery of a second specimen of *Perimestocrinus nevadensis* shows some variation in nodes on the brachs of this species. Distal brachs may have a short blunt central spine, and the *A*-ray primibrach has two blunt short nodes, one near the central proximal edge and the other at the apex of its branching distal end. Faint central blunt nodes occur on the anal *X* and right tube plate. In other respects this specimen is indistinguishable from the holotype. Because of variation in node development in one individual as just noted, the species is now considered without reservation to belong to *Perimestocrinus*.

The illustrated specimen is hypotype no. 45861.

PERIMESTOCRINUS OASIS Webster & Lane, new species

Plate 5, figures 9-10

Description.—Dorsal cup low, bowl-shaped with distinct basal concavity, plates smooth, sutures distinctly impressed. Infrabasal circlet small, confined to concavity, not visible in side view. Basals slightly tumid, strongly incurved at base forming outer edges of concavity; radials wider than high, gently convex, with distinct narrow interradial notches, radial facets and narrow shelf in front of which do not quite fill upper surface of radials. Three anal plates in cup, radianal almost separating anal *X* and posterior basal, in contact with *BC* basal; right tube plate small, almost out of cup. First primibrachs axillary in all rays, low, wide, with upper facets concave upward, so that apex of plate comes to narrow point; lower edge of each primaxil with narrow flat area just above articular surface with radial; succeeding brachs uniserial, gently rounded transversely with flat lateral sides, wedge-shaped in outline, and with second branching on fifth secundibrach in observable rays. Secundaxils produced into a short blunt spine just below the apex. Higher parts of arms, stem and tegmen unknown.

Remarks.—Perimestocrinus oasis Webster & Lane, n. sp., differs from the associated *P. nevadensis* in having flat rather than rounded arms that are more closely appressed, lacking short blunt spines on the primaxils, which are much lower, differently shaped plates in the new species, and in having relatively higher radial plates that do not have as conspicuous interradial notches.

Name.—The Greek noun *oasis* is used as new species name signifying the occurrence of this species close to the Moapa Valley warm springs.

Material.—The holotype and only known specimen is a partial crown, no. 45867.

Measurements.—Measurements on the holotype are (in mm.): HC (incompl.) 27.5; H, 7.0; W (est.), 18; HB, 5.0; WB, 6.0; HR, 5.3; WR, 9.0; $HIBrr_1$, 4.0; $WIBrr_1$, 8.4; $HIIBrr_1$, 2.2; $WIIBrr_1$, 4.6.

Genus SCHEDEXOCRINUS Strimple, 1961

Type species.—Schedexocrinus gibberellus Strimple, 1961.

SCHEDEXOCRINUS sp.

Plate 4, figure 8; Plate 8, figure 8

Description.—Crown large, mushroom-shaped, with greatly expanded tegmen cap above arms. Dorsal cup unknown. Arms probably branching on first primibrach. Lowest observed axillary plates large, wide and low, tumid, supporting a large tumid first secundibrach on each side, followed by three narrow secundibrachs that are several times wider than high. Secundaxils large, projecting, bearing large elongate spine that has apparently been broken off and regenerated on the two observable plates. All succeeding axils with long narrow spines, arms branching endotomously above secundaxils. Brachs wide, narrow, gently rounded transversely wedge-shaped, mostly uniserial but becoming biserially arranged in parts of some arms. Brachial just below each axil narrow, failing to extend completely across arm, resulting in a biserial condition.

Tegmen extending above arms, bearing large, wide cap of plates that consists of outer circlet of 13 large elongate plates with laterally directed, long slender spines; center of cap filled with large flat smooth polygonal plates.

Remarks.—Although the dorsal cup is missing from both available specimens of this species they can be assigned with confidence to *Schedexocrinus* because of the highly distinctive arms and tegmen cap, the specimens agreeing closely with Strimple's description of the genus. The large tegmen

cap would have measured at least 15 cm. in width if it were complete, and the complete crown would have been exceptionally large.

Material.—Two sets of reasonably complete arm fragments, both with tegmen cap intact are hypotypes nos. 45863 and 23682, the latter originally considered to be a paratype of *Synyphocrinus permicus.*

Family AMPELOCRINIDAE Kirk, 1942

Genus AESIOCRINUS Miller & Gurley, 1890

Type species.—*Aesiocrinus magnificus* Miller & Gurley, 1890.

AESIOCRINUS NODOSUS Webster & Lane, new species

Plate 6, figure 6

Description.—Crown small, spreading above cup; dorsal cup low bowl-shaped. Infrabasal circlet small, flat, largely covered by proximal end of stem, which is recessed into circlet; distal tips of infrabasals barely visible in side view of cup. Basals convex, slightly wider than high, each with horizontal row of four or five prominent nodes across center of each plate. Radials low, wider than high, with deeply depressed corners where two radials and basal meet; two small nodes at center of each radial, and narrow shelf just in front of facet. Ten arms; first primibrachs nonaxillary, tapering abruptly in width distally, occupying full width of radial plates, and with single, longitudinally elongate node on center of each plate. Second primibrachs axillary, triangular, as high as wide, with central elongate node. Secundibrachs strongly cuneate, each with a small elongate node that is offset to left or right on alternate brachs, producing zigzag keeled appearance to the arms. Anal sac unknown. Stem pentagonal.

Remarks.—*Aesiocrinus nodusus* is most closely related to *A. delicatulus* in the same fauna, differing from the latter in its different pattern of ornamentation, somewhat more robust arms, and in having distinctive depressions at the basal-radial corners. Most other species of *Aesiocrinus* are unornamented.

Name.—The new name *nodosus* is from Latin meaning full of knots or knotty, with reference to the prominent nodes of this species.

Material.—The only known specimen and holotype is no. 45865.

Measurements.—Measurements on the holotype are (in mm.): HC (incompl.), 32; HC, 6.9; WB, 4.0; HB, 3.1; WR, 8.5; HR, 4.0; HIBrr$_1$, 1.9; WIAxx, 4.3; HIAxx, 3.3; WIIBrr$_6$, 2.5.

Genus POLUSOCRINUS Strimple, 1951

Type species.—*Polusocrinus avanti* Strimple, 1951.

POLUSOCRINUS AMPLUS (Lane & Webster), 1966

Plate 5, figure 11

Aesiocrinus amplus Lane & Webster, 1966, p. 55, pl. 5, fig. 2, 4-5.

Because this species has a convex rather than concave base, and a relatively high dorsal cup it is transferred from *Aesiocrinus* to the related genus *Polusocrinus.* Some species of this latter genus have exceptionally thick cup plates and a tendency of the infrabasals to become fused into a single plate, features not observed in *P. amplus.*

The illustrated hypotype is no. 45864.

FAMILY, GENUS, AND SPECIES UNKNOWN

SPECIES D

Plate 2, figures 3-4, 8

A number of distinctive inadunate radials and brachials were obtained from etched samples that yielded *Platycrinites* sp. The deep radial facets with lateral prongs extending far into the cup, and similar configuration of brachials are unusual, and unlike any ossicles obtained from the main crinoid bed.

Illustrated specimens are a radial (hypotype no. 45866) and brachial (hypotype no. 45867).

SPECIES E

Plate 2, figure 11

Apart from single large columnals, each with several large cirral facets, that may represent parts of stem radices, the only specimen so far obtained of a root system is hypotype no. 45868.

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