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CARBONIFEROUS ECHINODERMS FROM THE
SOUTHWESTERN UNITED STATES

BY

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CARBONIFEROUS ECHINODERMS FROM THE SOUTHWESTERN UNITED STATES

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ABSTRACT—Study of Late Mississippian into Middle Pennsylvania age crinoids and blastoids found in Nevada, Arizona, and Utah suggests that they occur in sufficient numbers to be of stratigraphic value in the western United States. One species, *Paragassizocrinus calyculooides* (Lane) is a good index fossil for upper Morrowan strata in the Great Basin.

Two species of the blastoid *Pentremites* are recognized, one, *P. aridus*, is new. Crinoids assignable to 19 genera are described with 14 new species recorded: *Kallimorphocrinus inaquosus*, *K. inhumectus*, *Plummericrinus torroridus*, *Perimestocrinus quintorus*, *Metaperimestocrinus verrucosus*, *M. squarrosus*, *Stenopeocrinus pedersenorum*, *Sciadiocrinus brewi*, *Scytalocrinus reconditus*, *Aesiocrinus? inflatus*, *Endelocrinus solus*, *Paradelocrinus nederi*, *Synarmocrinus carrizoensis*, and *Poteriocrinus cavus*.

INTRODUCTION

RELATIVELY few crinoids or blastoids have been found or reported from west of the Rocky Mountains in the conterminous United States, despite large available areas of exposed marine Paleozoic rocks. The fact that few papers have been published on western Carboniferous echinoderms is due partly to a lack of paleontologists specifically interested in this area of study. The geographic sparseness of specimens may be attributable to geologists and paleontologists not searching expressly for fossil crinoids and blastoids. We hope this report may alert other paleontologists doing field work in the western United States to the possibility of finding Carboniferous echinoderms.

The best known western Carboniferous faunas are those of Early Mississippian age from New Mexico, Arizona, and Montana. Crinoids from the Lake Valley, New Mexico, area have been described by Miller (1881), Wachsmuth & Springer (1897), Bowsher (1955), and Strimple & Koenig (1956), and blastoids by Macurda (1964b, 1965). Echinoderms from the Redwall Limestone of Arizona include both crinoids and blastoids (Brower and Macurda, in press). The third well-known fauna is from the Lodgepole Member of the Madison Formation of Montana, described by Miller & Gurley (1897), Meek (1872) and Laudon & Severson (1953), among others. All three of these faunas have been judged to be of closely comparable age, upper Kinderhook to lower Osage, although there are some conspicuous differences in generic and species composition among the three faunas. Probable reasons for these faunal differences have not yet been investigated, and evaluation of the relative importance of biogeography, environmental control, and slight age

differences may depend on discovery of crinoids at geographically intermediate localities.

Isolated crinoid specimens of comparable Mississippian age have been reported by White (1877) from the Monte Cristo Limestone of southern Nevada. Mississippian echinoderms of lower Kinderhook, upper Osage, or Meramec age have not been described from west of the Rockies with the exception of blastoids from the Brazer Limestone of Utah (Peck, 1930). Chester echinoderms include a single blastoid species (Macurda, 1964a), and one crinoid (Lane, 1964), which was erroneously considered early Pennsylvanian in age.

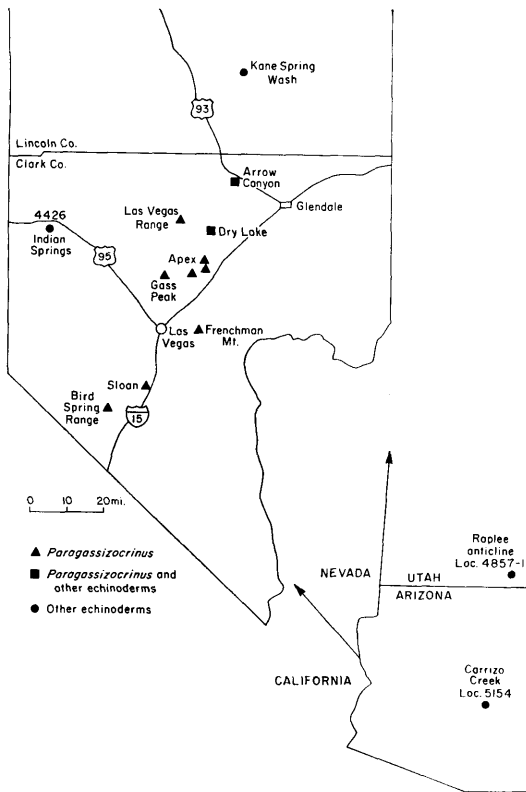
Pennsylvanian echinoderms include isolated specimens from Utah (White, 1876), two species from southern Nevada (Lane, 1964), an unidentified dorsal cup from the Ely Limestone of east-central Nevada illustrated by Lane (1962), and Morrowan cups and crowns from the Bridal Veil Falls Member of the Oquirrh Formation near Provo, Utah (Washburn, 1968).

It is clear to us that Carboniferous echinoderms are much more abundant and geographically widespread than is indicated by published accounts. We have either seen collections of, or have collected, crinoids from the Monte Cristo Limestone of southern Nevada and southeastern California, the Joanna Limestone of Nevada and Utah, the Lodgepole of Wyoming, Chester rocks in Utah, the Desmoines of Colorado, and the Desmoines and Virgil of New Mexico.

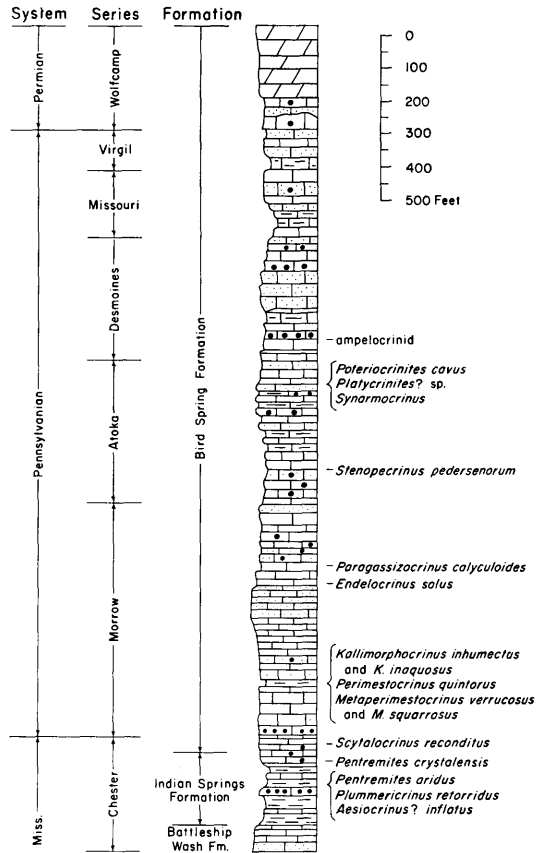
ECHINODERMS STUDIED

This report includes descriptions of specimens assignable to 19 genera of Carboniferous crinoids, and one blastoid, from southern Nevada, Arizona and Utah (Text-fig. 1). The preserva-

tion of the crinoids is adequate for assignment to 16 species, 14 of which are new. In addition, two specimens are assignable only to family, one a Pennsylvanian flexible crinoid (family Sagenocrinitidae), the other an ampelocrinid. Two disparid inadunates, both new species of the microcrinoid genus *Kallimorphocrinus*, are reported from Morrow rocks in southern Nevada (Text-fig. 2). Characteristic stem ossicles of the monobathrid camerate, *Platycrinites?*, are reported from Atoka rocks in southern Nevada. All of the other inadunate crinoids are advanced poteriocrinitid types typical of Late Mississippian and younger Paleozoic rocks elsewhere. Two of the crinoid genera are Chester in age, the other 17 are from lowest Morrow to Desmoines Pennsylvanian rocks. Two species of the blastoid *Pentremites*, one new, are reported from Chester rocks in southern Nevada. A summary of the echinoderms described and the areas and ages of rocks from which they were collected is as follows:



TEXT-FIG. 1—Locality map for Carboniferous echinoderms from southern Nevada, southern Utah, and eastern Arizona.



TEXT-FIG. 2—Stratigraphic column for southern Nevada, based on Arrow Canyon section, showing stratigraphic position of echinoderms from southern Nevada.

Southern Nevada, Bird Spring Formation

Desmoines: Family Ampelocrinidae, Species B
 Atoka: *Poteriocrinites cavus* n. sp.; *Platycrinites* sp.; *Synarmocrinus brachiatus* Lane, 1964; *Stenoperocrinus pedersenorum* n. sp.

Morrow: *Paragassizocrinus calyculoides* (Lane), 1964; *Endelocrinus solus*, n. sp.; *Kallimorphocrinus inhumectus* n. sp.; *K. inaquosus* n. sp.; *Metaperimestocrinus verrucosus* n. sp.; *M. squarrosus* n. sp.; *Perimestocrinus quintorus* n. sp.; Family unknown, Species D.

Chester: *Scytalocrinus reconditus* n. sp.

Southern Nevada, Indian Springs Formation

Chester: *Pentremites crystalensis* Macurda, 1964; *P. aridus* n. sp.; *Plummericrinus retorridus* n. sp.; *Aesiocrinus? inflatus* n. sp.; *Parulocrinus vetulus* (Lane), 1964.

Eastern Arizona, Naco Formation

Desmoines: *Paradelocrinus nederi* n. sp.; *Endelocrinus* sp.; *Delocrinus* sp.; *Sciadiocrinus brewi* n. sp.; *Synarmocrinus carrizoensis* n. sp.; *Parethelocrinus* sp.; Family Sagenocrinitidae, Species A; Family unknown, Species C.

Southern Utah, Paradox Formation

Desmoines: *Erisocrinus typus* Meek & Worthen, 1873.

Too few crinoids are known as yet from an insufficient number of localities to attempt any zonation of western Carboniferous rocks. However, some generalities can be made concerning the relative abundance of different kinds of crinoids in stratigraphic sequence from the Chester through the Desmoines in the Southwest.

In addition to *Pentremites*, which has not been found in Lower Pennsylvanian rocks in the southwestern United States, Chester rocks contain *Scytalocrinus*, a genus reported by Laudon (1941) to be especially common in the upper Chester Pitkin Limestone of Oklahoma. The presence of *Plummericrinus* and *Aeisocrinus*? in Chester rocks is unexpected, neither of these genera having been reported previously from rocks older than the Morrow.

The Morrow rocks of southern Nevada contain three species assignable to the Pirasocrinidae. Although several representatives of this large family are known from Morrow rocks in the Midcontinent, the family is more abundant and diversified in younger Pennsylvanian strata.

Paragassizocrinus calyculoides has now been found at ten localities over an outcrop distance of 75 miles in southern Nevada. The distinctive cup ossicles, especially the infrabasal circlet of this species can be recognized in a disarticulated state in the field. Although complete cups or crowns are quite rare, silicified individual cup plates may be abundant in limestone beds, and readily released with acid. Washburn (1968) reported *P. calyculoides* (as *Globocrinus bulbosus*) from the late Morrowan part of the Oquirrh Formation in central Utah. This indicates that *P. calyculoides* is widespread in the Great Basin Morrowan rocks and therefore an important index fossil.

The Atokan crinoids so far known from this area are an unusual assemblage unlike any fauna of comparable age in the Midcontinent. *Platycrinites*? is rare, but sporadically represented by distinctive columnals in Pennsylvanian rocks elsewhere. *Synarmocrinus* has been reported only from the Middle Pennsylvanian of Arizona, Nevada, and Oklahoma and Lower Pennsylvanian of Utah. The species assigned

here to *Poteriocrinites* is unlike other Pennsylvanian crinoids and has great similarity to Lower Carboniferous crinoids of western Europe.

The Desmoines crinoids from Arizona and Utah are a typical assemblage of this age, consisting of species assignable to the Pirasocrinidae, Erisocrinidae and Ethelocrinidae. The dominance of erisocrinids is typical of many upper Middle and Upper Pennsylvanian crinoid faunas elsewhere.

ACKNOWLEDGEMENTS

We thank the following: Mrs. Peter B. Kurtz and Miss Julie Guenther for drafting the line illustrations; Jay Inge and Mrs. Jerry Mathews for sketching the specimens of *Kallimorphocrinus*; Douglas Brew who discovered the Carrizo Creek locality and collected part of the material; and Irving Neder who helped in collecting.

Our field work has been supported by the Research Committee of the Academic Senate, University of California, Los Angeles. Part of the field work by Webster was supported by a fellowship from Standard Oil Company for 1962-63.

Photographs were made by us and negatives are on file in the Geology Department, University of California, Los Angeles.

SYSTEMATIC PALEONTOLOGY

Morphologic terms used in the blastoid descriptions follow those of Fay (1961). Crinoid terminology and abbreviations follow Moore & Plummer (1940), with dimension terms such as length, width, and depth after Lane & Webster (1966). All specimen numbers refer to the UCLA Department of Geology invertebrate fossil collections except those preceded by NAM, which are specimens collected by Douglas Brew and deposited in the Northern Arizona Museum, Flagstaff, Arizona.

Phylum ECHINODERMATA

Subphylum CRINOZOA Matsumoto, 1929

Class BLASTOIDEA Say, 1825

Order SPIRACULATA Jaekel, 1918

Family PENTREMITIDAE d'Orbigny, 1851

Genus PENTREMITES Say, 1820

Type species.—*cncrina Godonii* DeFrance, 1819, subsequent designation (Etheridge & Carpenter, 1886)

PENTREMITES CRYSTALENSIS Macurda, 1964a, Pl. 56, figs. 7,8

Pentremites crystalensis MACURDA, 1964a, p. 709-710, Pl. 116, figs. 8-11.

Diagnosis.—A *Pentremites* of the *P. sulcatus* group of Galloway & Kaska (1957, p. 63); calyx ovoid, moderate size, three small basal nodes on very broad pelvis, strongly convex vault, truncate at summit, pelvic angle averages 141 degrees, ambulacra concave, interambulacra slightly concave, five hydrospires per ambulacral side.

Description.—See Macurda (1964a, p. 709).

Remarks.—Specimens of *Pentremites crystallensis* were found to be locally abundant in all of the sections investigated by Webster (1969) in southern Nevada except at Arrowlime Quarry and Apex. Most specimens are crushed or fragmentary. The Kane Spring Wash section (UCLA locality 5243-22) yielded two partially silicified specimens, one of which is illustrated (Pl. 2, figs. 7-8). Specimens from this study compare closely to topotype material (UCLA 39413, three specimens) collected at Crystal Wash.

Types.—Hypotype, 34190.

PENTREMITES ARIDUS Webster & Lane, n. sp.
Pl. 56, figs. 1-6

Description.—Calyx ovoid, greatest width at ambulacral tips, cross section pentagonal; pelvis moderately broad V-shaped; vault convex, probably subrounded up to truncate summit. The lengths of crushed specimens range from 13.0 to 14.5 mm; average maximum-minimum width varies from 8.1 to 10.5 mm; average height 13.5 mm, average width 8.9 mm, L/W 1.5. Vault to pelvis ratio varies from 3.7 to 5.1 mm, averaging 4.7 mm. Estimated pelvic angle ranges from 102 to 134°, average 115°. Ambulacra are flat to faintly convex; interambulacra slightly concave.

Three basals; azygous quadrate, two larger pentagonal; lack ornamentation; form approximately 2/3 of pelvis.

Five radials; extending adorally slightly over lower half of vault; radial sinus deep.

Five deltoids; dart-shaped, approximately twice as high as wide; adoral tips level with or extended slightly above summit, commonly broken off. Deltoid-radial suture V-shaped, approximately 60°. Five ambulacra; biconvex, long lanceolate, taper gradually; width at mid-vault height varies from 2.5 mm on small specimen to 4.1 mm on large specimen. Ambulacral rim faint at aboral tip, moderate at adoral end. Lancet plates occupy central half of ambulacral width, medial groove distinct. Side plates, one ambulacral pore each, three plates per mm. Lancet side plates suture indistinct except on weathered specimens. Transverse ridges medially grooved with small pit at lancet side plate suture.

Mouth central, surrounded by four spiracles and one anispiracle.

TABLE 1—MEASUREMENTS IN MM OF TYPE SPECIMENS OF *PENTREMITES ARIDUS*, N. SP.

| | Holo- type 34186 | Para- type 34187 | Para- type 34188 | Average |
|---------------|------------------------|------------------------|------------------------|---------|
| Length | 14.5 | 13.0 | 13.1 | 13.1 |
| Width-maximum | 13.6 | 11.0 | 11.0 | |
| -minimum | 7.4 | 5.2 | 5.4 | |
| -average | 10.5 | 8.1 | 8.2 | 8.9 |
| L/W | 1.4 | 1.6 | 1.6 | 1.5 |
| Vault | 10.4 | 10.7 | 10.2 | 10.4 |
| Pelvis | 2.8 | 2.0 | 2.0 | 2.3 |
| V/P | 3.7 | 5.3 | 5.1 | 4.7 |
| Pelvic Angle | 108° | 102° | 134° | 115° |

Measurements.—See Table 1. All measurements are approximate, taken on crushed specimens. The values for length are undoubtedly large due to crushing; this would result in a larger than actual value for L/W.

Remarks.—All specimens of *Pentremites aridus* are either crushed or fragmentary and from the middle shales of the Indian Springs Formation (Chester) at the Dry Lake locality. *Pentremites aridus* belongs to the *P. godoni* group and is most closely related to *P. biconvexus*, a species reported from Lower Chester rocks (Galloway & Kaska, 1957, p. 47). *Pentremites aridus* differs from *P. biconvexus* in that the former has more concave interambulacra and the adoral tips of the deltoids extend to or slightly above the summit.

The specific name is from Latin, *aridus*, for dry, in allusion to the arid area where the specimens were found.

Material.—Three crushed calyces and 16 fragmentary plates or calyces.

Types.—Holotype, 34186; paratypes, 34187-34189.

Class CRINOIDEA J. S. Miller, 1821

Subclass CAMERATA Wachsmuth & Springer, 1885

Order MONOBATHRIDA Moore & Laudon, 1943

Family PLATYCRINITIDAE Bassler, 1938

Genus PLATYCRINITES Miller, 1821

Type species.—*Platycrinites laevis* Miller, 1821, original designation

PLATYCRINITES sp.

Pl. 56, fig. 9

Description.—Columnals elongate-oval, 21 to 23 mm long, 7 to 9 mm wide, and 2 to 3 mm high; outer sides of columnals with an irregularly wavy median horizontal ridge; fulcral ridge narrow, prominent, with deeply concave surfaces on either side; lumen minute.

Remarks.—These Middle Pennsylvanian co-

lumnals are similar to other large, highly elongate Pennsylvanian and Permian platycrinoid columnals described from various parts of the world. The fulcral ridges on either side of a single columnal are parallel, rather than being set at an angle, as in most Mississippian *Platycrinites* with a corkscrew-type stem. Offset columnals, such as those described from the Lower Permian of Nevada (Webster & Lane 1967) and the Middle Carboniferous of Russia, with fulcral ridges set at a large angle, have not been found.

Material.—Eight columnals on a single slab of limestone are hypotype 47207.

Locality.—The columnals were found at UCLA locality 4426, southwest of Indian Springs, Nevada.

Subclass FLEXIBILIA Zittel, 1879
Order SAGENOCRINIDA Springer, 1913
Family SAGENOCRINITIDAE Bassler, 1938
GENUS AND SPECIES UNKNOWN
SPECIES A

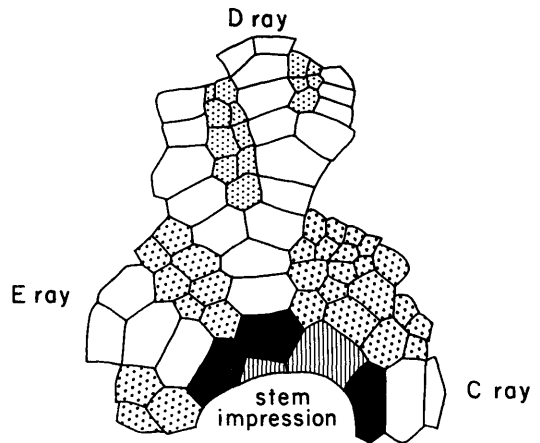
Pl. 56, fig. 16; Text-fig. 3

Description.—Crown large, incompletely preserved, interradial and interbrachial areas slightly depressed below rays, faint granulose ornament preserved in one small area, patelloid processes not evident, either poorly developed or poorly preserved; infrabasals completely under proximal columnal, not preserved; distal edge of DE basal projecting beyond stem impression; CD basal large, six-sided, completely separating C and D radials; supporting three anal plates above; radials wider than high, supporting two primibrachs in each ray, each of which is approximately as large as a radial; three secundibrachs on each side above primaxil, and three or four tertibrachs above each side of only preserved tertaxil; two quartibrachs are highest preserved brachs; secundibrachs separated by intersecundibrachs, one intersecundibrach notching upper edges of secundibrachs 1, and separating secundibrachs 2, followed by four ranges of two plates each, intertertibrachs preserved with one plate in the first range, and two plates in each of three succeeding rows; first regular interradial relatively small, notching upper edges of radials, followed by four ranges of two plates each, higher parts of interrays not preserved; posterior interray broad, with numerous plates; large anal (?radial) on right shoulder of CD basal in contact with C radial and first primibrach on right side and two large median anals on left; followed distally by one or two additional plates; a median series of three large anals is directly above the posterior basal; these plates gradually curve inward and

may have supported an anal tube; the left shoulder of the CD basal supports an anal plate that is smaller than the other two anals just above the basal, has six sides, is in contact with the D radial and first primibrach of the D ray, and supports two anal plates above; these two plates are followed by at least 13 plates that become progressively smaller distally and are in contact with secundibrachs on the left and the median series of anal plates on the right. The stem is not preserved.

Measurements (mm).—Greatest preserved length of ray 40; height and width, D radial, 4.6, 7.5; height and width, primibrach 1, 4, 8; height and width, primaxil, 4.5, 8; height and width, secundaxil, 4.2, 8; height and width, tertaxil, 3.1, 6.5; height and width, CD basal, 4.8, 7.7.

Remarks.—The single partial crown of a Pennsylvanian flexible crinoid on which this description is based probably represents a new genus. The specimen is judged, however, to be too incomplete to serve satisfactorily as the holotype of a type species. Among other Pennsylvanian and Permian flexibles with a generally similar configuration of plates, the Arizona specimen may be most closely related to *Trampidocrinus* from the Lower Permian of southern Nevada. It differs from *Amphicrinus* and *Synerocrinus* in having three anals next above the posterior basal rather than one, and in having many more plates in the posterior interray. In addition, these two named genera lack interbrachials above the secundaxils. *Trampidocrinus* has two, three, or four plates next above the posterior



TEXT-FIG. 3—Plate diagram of flexible crinoid, Family Sagenocrinitidae, Species A. Basals vertically ruled, radials black, interradials and anal plates coarse stipple, interbrachials fine stipple, ray plates white.

basal, numerous plates in the posterior interray, and interbranchials above the secundaxils and tertaxils. Diagnostic features of this Permian genus include a unique bent stem and development of an *E-BC* symmetry plane in the proximal part of the cup. The stem and much of the lower part of the cup of the specimen described here are not preserved and so close comparison with *Trapidocrinus* cannot be made.

Material.—A single incompletely preserved crown, NAM G2.8688, is from the Naco Formation along Carrizo Creek, Arizona, UCLA locality 5154.

Subclass INADUNATA Wachsmuth & Springer,
1885
Order DISPARIDA Moore & Laudon, 1943
Family ALLAGECRINIDAE Carpenter & Etheridge,
1881

Genus KALLIMORPHOCRINUS Weller, 1930

Type species.—*Kallimorphocrinus astrus* Weller,
1930, original designaton

KALLIMORPHOCRINUS INAQUOSUS Webster &
Lane, n. sp.
Pl. 58, figs. 1,2

Description.—Calyx small, pyriform, height equals width to slightly wider than high, flattened oral surface in side view, star-shaped in oral or aboral views, monocyclic. Three BB, sutures barely discernable, small, wider than high, quadrilateral, proximal half flat, forming stem facet; distal half flares upward and outward. Five hexagonal RR, flare upward, approximately twice as wide distally as proximally, height twice medial width, prominent medial longitudinal rounded angular ridge extends from proximal tip distally, truncated by beveled triangulation at distal extremity. Five rounded petalose OO, with a shallow spatulate depression on upper surface of each; OO overlap concavities between subjacent radial angulations; CD oral in contact with all other orals; BC and DE orals each in contact only with two adjacent orals; EA and AB orals in contact with two adjacent and CD oral; oral cirlet projects as a prominent cap above radial cirlet.

Anal plate not developed. Ornamentation fine irregular pits over all calyx plates and proximal columnal. Columnal round, crenellate, axial canal round.

Measurements (mm).—Holotype, 34194, height 1.2, maximum width 1.3; paratype, 34195, height 0.9, maximum width 0.9.

Remarks.—Study of growth stages (nine specimens) of *Kallimorphocrinus inaquosus* shows a decrease in the relative size of the orals to the calyx with continued growth as was shown for

K. angulatus by Strimple & Koenig (1956, p. 123, Text-fig. 2, 13–28). *Kallimorphocrinus inaquosus* most closely resembles *K. piasaensis* Weller, 1930, of Late Desmoines age, but differs in that the latter has articular facets and pits on the distal surface of the radials.

The specific name is from Latin, *inaquosus*, for lacking water, dry, in allusion to the climate where the specimens were found.

Material.—Nine specimens from the Lower Morrow part of the Bird Spring Formation, Arrow Canyon, Nevada.

Types.—Holotype, 34194; paratypes, 34195–34196.

KALLIMORPHOCRINUS INHUMECTUS Webster &
Lane, n. sp.
Pl. 58, fig. 3

Description.—Calyx small, subpyriform, slightly wider than high, star-shaped in oral or aboral views, monocyclic (?). Three quadrilateral BB, sutures faint, proximal part covered by column but appears flat for stem facet, distal half flaring upward. Five hexagonal RR, distal ends approximately one-fourth again as wide as proximal, height twice proximal width, prominent angular ridge extending from proximal end to beveled distal end; small shallow pit on distal end ventral to bevel. Five small OO, rounded petalose, restricted to ventral surface and do not overlap interradian concavities, faint depression on each oral surface; CD oral in contact with all other orals; BC and DE orals in contact only with two adjacent orals; EA and AB orals in contact with two adjacent and CD orals.

Rounded shallow anal pit shared by mutual distal shoulders of C and D radials. Ornamentation of fine irregular pits covering all calyx plates and preserved proximal columnal. Columnal round, crenellate, axial canal round.

Measurements (mm).—Height 1.3; width 2.0.

Remarks.—*Kallimorphocrinus inhumectus* differs from *K. inaquosus* in that the former has the orals restricted to the ventral part of the radial cirlet, possesses an anal pit, and appears more sharply angular. *Kallimorphocrinus inhumectus* resembles *K. indianensis* Weller, 1930, a species reported from rock of Middle Pennsylvanian age, but has less well-developed articular facets and pits, a smaller oral cirlet, and more angular interradian concavities.

The specific name is Latin, *inhumectus*, for not moist, dry, referring to the climate of southern Nevada.

Material.—One specimen from Lower Morrow part of Bird Spring Formation at Arrow Canyon, Nevada.

Types.—Holotype, 34197.

Order CLADIDA Moore & Laudon, 1943

Suborder POTERIOCRINITINA Jaekel, 1918

Family PACHYLOCRINIDAE Kirk, 1942

Genus PLUMMERICRINUS Moore & Laudon, 1943

Type species.—*Pachylocrinus mcquirei* Moore, 1939, original designation

PLUMMERICRINUS RETORRIDUS Webster & Lane,
n. sp.

Pl. 55, figs. 20,21,26

Description.—Dorsal cup medium-low, truncate bowl-shaped, with a shallow basal concavity and slightly outflaring walls. Crushed IBB concealed by broad proximal columnal. Five hexagonal BB (BC basal heptagonal), wider than high, strongly convex longitudinally, gently convex transversely, extreme proximal tips in basal impression, distal tip nearly vertical, short interbasal sutures, all articular surfaces centrally depressed with denticulate rims. Facet occupies full width of radial, gently slopes outward; transverse ridge shorter, dorsal to maximum width of radial, denticulate; outer ligament area narrow, outer marginal ridge sharp, outer ligament furrow very narrow, outer ligament ridge denticulate, coalesces with transverse ridge laterally, ligament pit furrow grades into ligament pit with no apparent break, ligament pit moderately deep and only slightly inclined ventrally; inner ligament area deep, intermuscular furrow wide, moderately deep, grades into intermuscular furrow, oblique furrow shallow, basin-shaped, merges dorsally into undulatory muscle area with no oblique ridge; lateral ridge sharp with nearly vertical adsutural slope, narrow long adsutural platform. Posterior interray wide, gently convex transversely and longitudinally. Three anals in cup, normal arrangement; RA pentagonal bordered by C radial, BC basal, CD basal, anal-X, and rt; anal-X hexagonal, slightly higher than wide, supported by CD basal, projects above summit; rt not present on specimen, space left shows it would have been supported by RA and projected above summit. Ornamentation is a microscopic granular texture covering all cup plates. Sutures faintly impressed with dimples at angles of BB and RR. IBr wider than high, strongly convex transversely, gently convex longitudinally, axillary in the three rays that are present. IIBr₁ quadrangular, rounded exterior. Distal arms and anal sac unknown; column round.

Measurements (mm).—H 6.3; W (max) 16.2; W (min) 10.8; W (average) 13.5; H/W ratio 0.47; HB 4.0; WB 5.1; HR 4.4; WR 6.6; HIBr 4.5; WIBr 6.2; HIIIBr₁ 2.6; WIIIBr₁ 4.6.

Remarks.—In general appearance and size *Plummericrinus retorrinus* is similar to *P.*

uddeni (Moore & Plummer), reported from the Mineral Wells Formation, Des Moines and/or Missourian, of Texas, but it differs from the latter in having a granular ornamentation. *Plummericrinus retorrinus* is easily distinguished from all other described species of the genus by the short interbasal sutures.

The specific name, *retorrinus*, is Latin for dried up, in allusion to the dry lakes to the east and west of where the specimen was found.

Material.—One partial crown and one dorsal cup fragment from the upper shales of the Indian Springs Formation (Chester) at the Dry Lake section, UCLA locality 5248-16c.

Types.—Holotype, 34192; paratype, 34193.

Family PIRASOCRINIDAE Moore & Laudon, 1943

Genus PERIMESTOCRINUS Moore & Plummer,
1938

Type species.—*Hydreionocrinus noduliferus* Miller & Gurly, 1894, original designation.

PERIMESTOCRINUS QUINTORUS Webster & Lane,
n. sp.

Pl. 55, figs. 22,23

Description.—Cup low truncate bowl-shaped, flat base, deep basal concavity. Five? IBB, confined to deep basal concavity covered by proximal columnals and matrix, not visible. Five BB, strongly convex longitudinally and moderately convex laterally; proximal ends downflared forming walls at basal impression; distal half upflared, visible in side view; central node in center of each basal, otherwise dorsal surface smooth; articular surfaces concave with denticulate rims. Five pentagonal RR, vertical in distal part, moderately convex longitudinally and laterally; articular surfaces except facet concave with denticulate rims; shallow but obvious notch at distal end of interrarial suture. Facet not as wide as radial width, slopes outward at 10-15°; outer ligament area narrow, consists of faint outer marginal ridge and furrow, and shallow ligament pit; transverse ridge denticulate. Inner ligament area deep, contains a faint central pit on an intermuscular ridge with a shallow intermuscular furrow merging into intermuscular notch, shallow oblique furrows ending in pits on side of intermuscular ridge, indistinct oblique ridges, merging with muscular arcs and smoothly undulating lobate muscle areas bounded laterally by steep adsutural slopes. Posterior interradius wide, convex outward, making cup appear hexagonal in outline in oral or aboral view. Three anals: radianal pentagonal surrounded in clockwise direction by C radial, BC basal, CD basal, anal-X, and rt; anal-X elongate hexagonal, half above summit; rt hexagonal, less than half below summit. Fragments of

three primibrachs suggest first primibrach axillary, higher than wide, and not spinose. Stem round, arms and anal sac unknown.

Measurements (mm).—H 4.9; W 10.7; H/W ratio 0.46; HB 3.8; WB 4.0; HR 3.5; WR 5.5; WBr₁ 5.0.

Remarks.—One radial plate in the cup of the holotype of *Perimestocrinus quintorus* has a centrally situated, laterally directed short spine that is not present, nor is there any suggestion of development of a similar structure, on any other radial of the holotype or loose radials from the same locality. The spine is believed to be an aberrant structure and not characteristic of the species. *Perimestocrinus quintorus* is most closely related to *P. pumilis* Moore & Plummer, 1938, a species reported from the Brentwood Limestone, Morrow age, of Oklahoma. It differs from the latter species in that *P. quintorus* has more convex radials and basals, with development of a central node on the basals, and facets that do not slope outward as steeply.

The specific name is derived from Latin, *quini* (five) and *torus* (round elevation) in reference to the five nodes, one on each basal.

Material.—One partial crown and six loose ossicles from the Middle Morrow part of the Bird Spring Formation, Arrow Canyon, Nevada.

Types.—Holotype, 43122; paratypes, 43123.

Genus METAPERIMESTOCRINUS Strimple, 1961

Type species.—*Metaperimestocrinus spiniferus* Strimple, 1961, original designation

METAPERIMESTOCRINUS VERRUCOSUS Webster & Lane, n. sp.

Pl. 55, figs. 18,19; Pl. 57, figs. 10–15

Description.—Cup low to medium-height truncate bowl-shaped; base flat with shallow depression. Five quadrangular IBB, dart-shaped, proximal part subhorizontal depressed for stem impression, distal parts slightly downflared, not visible in side view, interinfrabasal articular surfaces moderately deep concavities rimmed with denticulate ridges. Five hexagonal BB (BC or CD basal is heptagonal depending upon shape and position of radianal), strongly convex longitudinally, proximal tip downflared forming outer rim of basal impression, distal four-fifths upflared, visible in side view; all articular surfaces moderately deep concavities rimmed with denticulate ridges. Five pentagonal RR (except D radial which is hexagonal), wider than high, flaring slightly outward to vertical in distal extremities; radial-basal articular surfaces moderately deep concavities rimmed

with denticulate ridges; interradial articular surfaces triangular, shallow, flat-bottomed concavities rimmed with denticulate ridges. Radial facet deep and wide, subhorizontal to slightly outward sloping, extending maximum width of radial. Outer ligament area is formed by: a narrow sharp-crested outer marginal ridge; a narrow moderately deep outer ligament furrow; a denticulate outer ligament ridge which coalesces with transverse ridge on distal extremities; and a centrally located moderately shallow ligament pit of length less than one-third radial width merging laterally on distal ends into weakly developed ligament pit furrow. Transverse ridge denticulate throughout length, finer denticles than in outer ligament ridge, flat crest. Inner ligament area contains; a faint central pit on an intermuscular ridge; a shallow intermuscular furrow on ventral part of intermuscular ridge, grades ventrally into intermuscular notch; an oblique furrow, narrow, straight, moderately deep, extends from distal ends of radial to a shallow pit on each side of the intermuscular ridge, bounded ventrally by sharp-crested oblique ridge which merges with muscular area toward intermuscular ridge; a muscular area subtriangular lobe-shaped, slopes outward, surface irregular, slight indication of subparallel arcuate transverse ridges and grooves; a lateral lobe extending from oblique ridge to intermuscular notch. Adsutural platform narrow, widens ventrally, extending from oblique ridge to ventral edge of facet; adsutural slope steep dorsally becoming vertical and finally reclined under lateral ridge ventrally. Posterior interradius slightly indented, three anals below summit of cup, radianal variable, pentagonal or hexagonal, hexagonal when in contact with CD basal, normally pentagonal, in contact clockwise with C radial, CD basal, D radial, anal-X, and right tube plate; anal-X approximately half below summit. Right tube plate less than half below summit. Cup sutures strongly impressed, particularly in larger individuals, some dimpling at basal and radial apices. Surface of cup covered with irregular medium-size tubercles.

First primibrachs axillary with long well-developed spine, surface covered with same ornamentation as cup. Anal sac probably mushroom-shaped.

Column round, crenulate (32 crenellae on one cup) stem impression; lumen pentalobate.

Measurements.—See Table 2.

Remarks.—The abundant specimens and disarticulated material of *Metaperimestocrinus verrucosus* permit a study of detailed morphological features and growth stages. Growth stages show that deeper sutural impressions and more

TABLE 2—MEASUREMENTS IN MM OF TYPE SPECIMENS OF *METAPERIMESTOCRINUS SPINIFERUS*, N. SP.

| | Holotype 43126 | Paratype 43127 | Paratype 43128 | Paratype 43129 |
|------|-------------------|-------------------|-------------------|-------------------|
| H | 11.1 | 5.7 | 8.7 | 9.5 |
| W | 28.2 | 13.8* | 19.7 | 20.9 |
| H/W | 0.39 | 0.41 | 0.44 | 0.45 |
| WIBB | 8.8 | 4.5 | 6.7 | 7.2 |
| WIB | 4.3 | 1.8 | 3.2 | 3.6 |
| HB | 9.2 | 4.5 | 6.7 | 7.3 |
| WB | 11.2 | 5.3 | 8.0 | 8.1 |
| HR | 9.4 | 4.6 | 6.5 | 6.9 |
| WR | 16.2 | 7.3 | 11.3 | 11.7 |
| WS | 4.0 | 2.5 | 3.0 | 3.2 |

* Average of maximum and minimum values of slightly crushed specimen.

pronounced ornamentation develop in mature individuals. Only one poorly preserved cup (not illustrated) was found with an articulated primibrach; however, numerous loose primibrachs were found. One such primibrach shows development of a double spine, one immediately above the other, larger one proximal. This is believed to be an aberrant development. Several loose tegmen cap spines were found which are believed to belong to this species. They are covered with the same irregular medium-size tubercles and the articular surfaces have central moderately-deep concavities bordered by denticulate rims. The spines would have projected laterally to slightly upward and the ring of spine plates would have enclosed other plates at the apex of the anal sac.

Discovery of *M. verrucosus* extends the range of the genus, which has been reported from the Des Moines Series of the Midcontinent region. The stratigraphic range is now recognized as Morrow to Des Moines and the geographic range includes the Great Basin.

The specific name, *verrucosus*, is Latin meaning full of warts, in reference to the tuberculate ornamentation.

Material.—Eight complete and five partial cups, and numerous disarticulated cup, arm, and tegmen plates from the Middle Morrow part of the Bird Spring Formation, Arrow Canyon, Nevada.

Types.—Holotype, 43126; paratypes, 43127-43134.

METAPERIMESTOCRINUS SQUARROSUS Webster & Lane, n. sp.
Pl. 57, figs. 4,5

Description.—This species is similar to *Metaperimestocrinus verrucosus* and only differences between the two species are described. Sutures appear impressed due to moderately wide smooth shelf between suture and elevated coarsely tubercled areas on all radials and basals; obvious dimpling at angles of basals and radials. Facets slope gently outward; ligament pit moderately deep, slopes ventrally under transverse ridge. First primibrach axillary, distal tip protruded but not spinose, surface covered with coarse tubercles.

Measurements (mm).—H 10.9; W 28.8; H/W

EXPLANATION OF PLATE 55

All figures are $\times 1$ unless indicated otherwise

- Figs. 1-4, 6-13, 15-17, 24, 25, 27-29—*Paragassizocrinus calyculoides* (Lane). 1-4, 6-13, hypotypes 39492, 39493, 39495, 39496, external, internal, and lateral views of four infrabasal circllets showing variation in size, shape and thickness, loss of stem facet, and fusion of intra-infrabasal sutures, $\times 2$; 15-17, hypotype 39498, lateral, external and internal views of basal, $\times 2$; 24, 25, hypotype 39499, ventral and external views of radial, $\times 2$; 27-29, hypotype 34198, dorsal, CD-interray, and A-ray views of partial crown.
- 5, 14—*Scytalocrinus reconditus* Webster & Lane, n.sp. Holotype, 34191, CD-interray and A-ray views of partial crown.
- 18, 19—*Metaperimestocrinus verrucosus* Webster & Lane, n.sp. Paratype 43128, basal and CD interrayer views of dorsal cup.
- 20, 21, 26—*Plummericrinus retorridus* Webster & Lane, n.sp. Holotype 34192, CD-interray, dorsal, and E-ray views, $\times 2$.
- 22, 23—*Perimestocrinus quintorus* Webster & Lane, n.sp. Holotype 43122, CD-interray and dorsal views, $\times 2$.

